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Editorial.

The Design of Choke Coils and Transformers which Carry a Direct Current.

IN many of the choke coils and transformers employed in radio telegraphy and telephony, the alternating current is superimposed upon a direct current and it is now generally recognised that in these circumstances the effective inductance of the winding to the alternating current may be very much smaller than its value in the absence of the direct current. It is not so well known that the inductance in such a case can be increased by introducing an air-gap in the magnetic circuit. At first

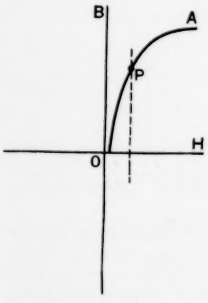


Fig. 1.

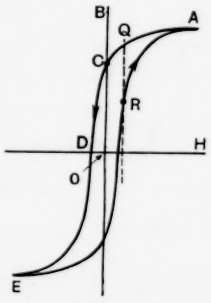


Fig. 2.

sight one would expect this to cause a decrease in the inductance, but while this is true of the inductance to an ordinary alternating current, it is not necessarily true when the alternating current is superimposed upon a direct current. If one takes a closed iron circuit which has never been magnetised since it was annealed and passes a gradually increasing current through a coil wound upon it, the relation between the magnetising force H, which is proportional to the current, and the flux density B, which is proportional to the total magnetic flux produced, will be as shown in Fig. 1. If we now decrease the current to zero, the magnetic flux does not retrace the same curve, but follows a curve like AC in Fig. 2, OC being the remanent magnetism which is very large even in soft iron if the magnetic circuit be closed. On increasing the current in the reverse direction we trace the curve CDE, where OD is the coercive force. If we now continually increase and decrease the current, first in one

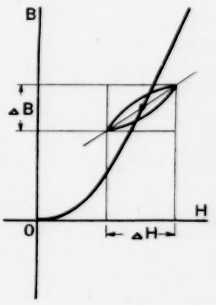


Fig. 3.

direction and then in the other, we go around the loop *ACDERA* and never again arrive at the condition shown by the curve in Fig. 1, unless we adopt special means for demagnetising the iron.

It will be seen that for a given magnetising force H, *i.e.*, for a given current, there are three different values of B, represented by the points P in Fig. 1 and Q and R in Fig. 2;

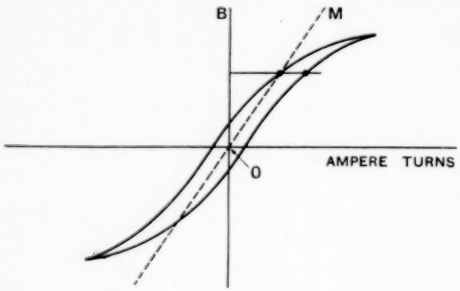


Fig. 4.

there will be other values of B for loops of different amplitude.

If the direct current be maintained at a value corresponding to any point on the curve and a small alternating current be superimposed upon it, it must not be imagined that one would run up and down the curves which we have just considered. The values of B and H would be found to trace out a small loop, with an axis inclined to the curve as shown in Fig. 3, so that for a given variation of the magnetising current, the variation of the flux would be smaller—in many cases considerably smaller—than one would have predicted from the curves of Figs. 1 and 2.

Consider now the effect of introducing an air-gap in the magnetic circuit. The permeability of air being always unity, the value of the ampere-turns required to drive the flux across the gap is strictly proportional to the flux density as represented in Fig. 4 by the line *OM*. For any given value of B the ampere-turns required for the iron part of the circuit will be unchanged, so that the total ampere-turns required are obtained by adding horizontally those for the air-gap and those for the iron. This has the effect of shearing over the loop of Fig. 1, as shown in Fig. 4. A given direct current will now produce a smaller value of B, and it may have the effect of bringing the centre point of the small A.C. loop down from the upper highly-saturated and flat part of the curve to an unsaturated and steep part where one may expect the small loop to be more steeply inclined. If this is so, then the effective inductance to the superposed A.C. will be increased. As the air-gap is increased, however, the line *OM* in Fig. 4 will turn further from the vertical, and the steepness of the large hysteresis loop and of the small A.C. loops will all become less and less. There will be some length of air-gap which will give a maximum value of the A.C. inductance in any given case. This optimum condition will depend to some extent on the amplitude of the superposed A.C., but one can simplify the problem by assuming that this is small compared with the steady D.C.

The ratio B/H at any point of the magnetisation curve is called the permeability at that point and is always designated by μ. In the present case, however, we are not so concerned with this ratio as with the ratio $\frac{\Delta B}{\Delta H}$ in Fig. 3. It will be noted that this is not the slope of the magnetisation curve, but the slope of the diagonal of the rectangle enclosing the A.C. loop. We shall use $\frac{\Delta B}{\Delta H}$ in this special sense and call it the incremental permeability μ_1. This subject has been studied by T. Spooner* and C. R. Hanna** and this article is based on data

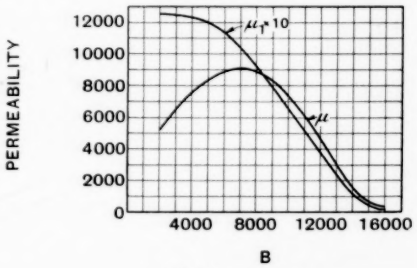


Fig. 5.

* T. Spooner, "Effect of a superposed alternating field on apparent magnetic permeability and hysteresis loss," *Physical Review*, 1925.

** C. R. Hanna, "Design of reactances and transformers which carry direct current," *Journal Amer. I.E.E.*, Feb. 1927.

obtained from their papers. Values of the ordinary permeability μ and the incremental permeability μ_1 for 4 per cent. silicon steel are given in Fig. 5.

In so far as the superposed alternating current is concerned we may define the self-inductance L as follows:—

$$L = \frac{\text{change of flux} \times \text{turns}}{\text{change of current}} \times 10^{-8} \text{ henries.}$$

If I = current in amperes, A = cross-section of core in sq. cms., and T = number of turns, then

$$L = \frac{AT}{10^8} \times \frac{\Delta B}{\Delta I}.$$

Now an increase of ΔB requires an increase ΔH in the magnetising force in the iron and an increase ΔB in that in the air-gap; hence if l_a = length of air-gap and l_i = length of path in the iron, $0.4\pi(\Delta I)\,T = \dfrac{\Delta B}{\mu_1} l_i + \Delta B \,.\, l_a$ = total increase in magnetomotive force.

Hence

$$L = \frac{0.4\pi A T^2}{\dfrac{l_i}{\mu_1} + l_a} \cdot 10^{-8} \text{ henries.}$$

Apart from any consideration of superposed A.C., we have

$$B = \frac{0.4\pi IT}{\dfrac{l_i}{\mu} + l_a},$$

and substituting for T in the formula for L, we have

$$L = \frac{B^2 A}{0.4\pi I^2} \cdot \frac{\left(\dfrac{l_i}{\mu} + l_a\right)^2}{\left(\dfrac{l_i}{\mu_1} + l_a\right)} \cdot 10^{-8}.$$

Now $l_i A = V$, the volume of the iron, and therefore

$$\frac{LI^2}{V} = \frac{B^2}{0.4\pi} \cdot \frac{\left(\dfrac{1}{\mu} + a\right)^2}{\left(\dfrac{1}{\mu_1} + a\right)} \cdot 10^{-8},$$

where a is put for the ratio l_a/l_i, which we may call the gap ratio.

For the steady magnetising current I we have also

$$\frac{IT}{l_i} = \frac{B}{0.4\pi}\left(\frac{1}{\mu} + a\right).$$

These two formulæ are employed by Hanna to develop a very simple graphical method of design. For an assumed value of the gap ratio a, several values of B are taken and from the corresponding values of μ and μ_1 (see Fig. 5), the values of LI^2/V

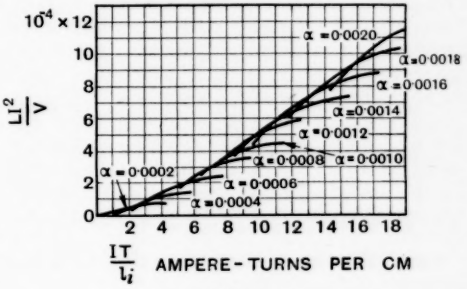


Fig. 6.

and IT/l_i are calculated, and the former plotted against the latter as shown in Fig. 6, which shows a number of curves obtained for different assumed values of a. A curve is drawn just touching all these curves, and it can be seen that this envelope curve gives the relation between LI^2/V and IT/l_i, if the best value of a is always chosen. It will be noticed that the ordinate LI^2/V is a quantity which, if divided by the square of the current, gives the inductance per cubic centimetre of the iron employed. The value of a to be employed at any point of the envelope curve is the value corresponding to the individual curve which is tangential at that point. In Fig. 7 the

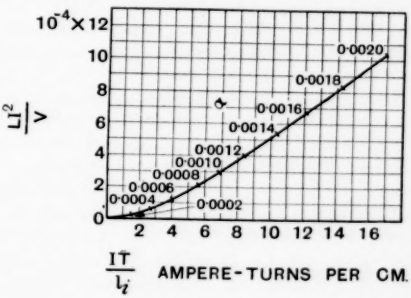


Fig. 7.

envelope curve is drawn and divided to indicate the values of a corresponding to different points on the curve. This curve is the working curve in the design. Suppose

that it is required to design a suitable winding and air-gap for an iron core of given dimensions, the continuous current I and the A.C. inductance L being given, LI^2/V can be calculated and the values of IT/l_i and α read off the curve in Fig. 7. This fixes the air-gap and the number of turns. If it is found impossible to get the requisite turns into the available space without an excessive resistance, then a larger iron core must be taken and the process repeated. The largest obtainable inductance from a given core is thus seen to be limited by the allowable resistance, the air-gap being always adjusted to the optimum value for the inductance.

It will be seen that the value of α lies between 0.2 and 2 parts in 1,000.

In the original paper, curves are also given for hypernik, a 50 per cent. nickel iron, and experimental results given showing a close agreement with calculation.

Before utilising the method it is necessary to determine the curve of incremental permeability μ_1 for the iron to be employed; little has been published on this subject. Apart from utilising the methods outlined in the design of new inductances it is obviously advisable to test any already in use with a view to determining whether their performance might not be improved by the introduction of an air-gap in their magnetic circuit. This only applies to those cases, and they are many, where the windings carry a direct current.

G. W. O. H.

Rectification as a Criterion of Distortion in Amplifiers.

By Manfred von Ardenne.

IF the pointer of a milliammeter connected in the plate circuit of an amplifying valve moves during reception, a rectifying effect is present which has a definite relation to the distortion. This method of stating the distortion by the detection effect and determining, in this way, the distortion factor, is very advantageous, as the measurements can be carried through comparatively easily and, moreover, the influence of the plate-circuit resistance on the curvature of the working characteristic is considered automatically. If the grid-currents remain smaller than 10^{-8} ampere, *i.e.*, in thoroughly evacuated valves, and the grid-voltages never get less negative than —1 volt, then the valve-distortion depends only upon the curvature of the static characteristic and on the valve and the kind of the resistance in the output circuit. When an alternating sinusoidal potential is impressed on the grid and the working characteristic is curved in the corresponding range, an alternating current is produced in the plate-circuit which contains not only the fundamental frequency but a number of harmonics, thus causing disagreeable distortion. The amplitude of the various harmonics could be deduced from the curvature of the working characteristic and the value of the alternating grid potential, but as the required physiological and acoustic researches had not yet been carried out, it would be useless at the present time to work out the amplitudes of the various harmonics, the more so as they will depend on the actual shape of the curvature. The production of harmonics due to the bend of the curve usually results in a change δI_a. Only when the working point is exactly on the inflection point of the characteristic is it likely that harmonics will be produced without noticeable rectification. This will happen occasionally in power amplifiers. In general practice, however, the distortion due to the lower bend is of far greater importance. So long, therefore, as the working characteristic is utilised only where the curvature is in one direction, it is possible to estimate the distortion from the detection effect. To get a measure for the distortion or, what amounts to the same thing—for the sensitivity of the rectifying effect—one may compare the variation δE_g

of steady grid potential which would cause the same variation δI_a of anode current with the amplitude E_g of the alternating grid potential which actually causes it. Thus

$$\delta E_g = \frac{\delta I_a}{S_r} \quad \ldots \quad \ldots \quad (1)$$

$$\text{and } K_v = \frac{\delta E_g}{e_g} \quad \ldots \quad \ldots \quad (2)$$

is a measure of the rectifying effect.

In the equation (1) S_r means the steepness of the static "working" characteristic in

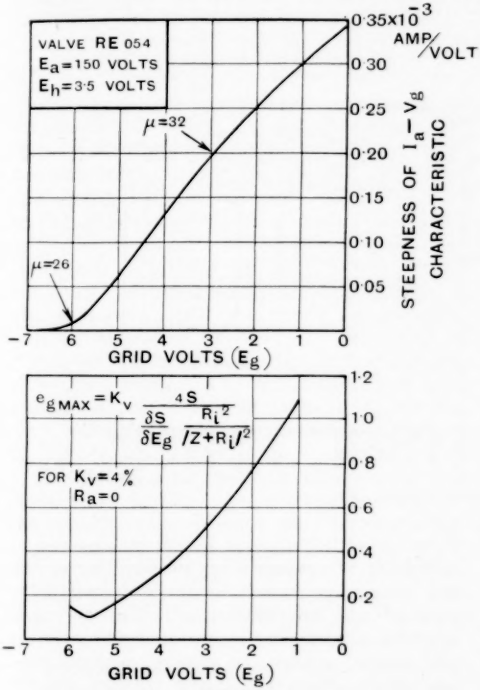


Fig. 1.

the respective point, *i.e.*, of the valve together with the anode resistance. This steepness S_r is related to that S of the valve itself by the formula $S_r = S \dfrac{R_i}{R_a + R_i}$. The current increment δI_a of a valve with any plate circuit arrangement of impedance Z will amount to

$$\delta I_a = \frac{\partial S}{\partial E_g} \cdot \frac{R_i^2}{|Z+R_i|^2} \cdot \frac{e_g^2}{4} \cdot \frac{R_i}{R_a+R_i} \quad \ldots \quad (3)$$

$|Z+R_i|$ means the absolute value of the joint impedance of the valve and anode circuit.

In the above equation $\partial S/\partial E_g$ represents the curvature of the static valve-characteristic. The factor

$$\frac{\partial S}{\partial E_g} \cdot \frac{R_i^2}{|Z+R_i|^2}$$

may be regarded as the curvature of the dynamic characteristic. It is obvious, that the effective curvature of the dynamic working characteristic decreases rapidly as the value of the plate circuit resistance exceeds that of the valve itself (R_i). From equations (1) and (3) the following relation is obtained for the distortion factor

$$K_v = \frac{\dfrac{\partial S}{\partial E_g} \cdot \dfrac{R_i^2}{|Z+R_i|^2}}{4.S} \cdot e_g \quad \ldots \quad (4)$$

This equation shows that the potentials to

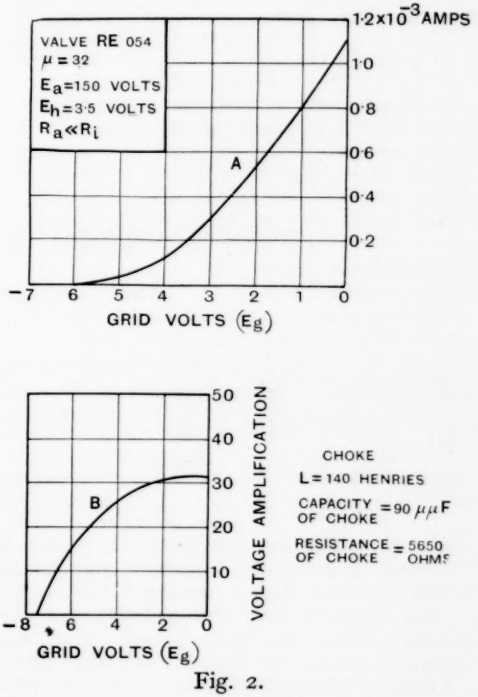


Fig. 2.

be applied to the grid, without exceeding the critical distortion factor, are inversely proportional to the curvature of the dynamic

working characteristic. Experiments carried out with a Western Electric loud-speaker and with the aid of trained musicians showed that in transmitting orchestral music a distortion factor in the power stage of less than about 4 to 6 per cent., and in the last stage but one less than 4 per cent., is necessary.

It is often interesting to ascertain how large the grid-potential input may be without exceeding the critical distortion ascertained for a distortion factor of 4 per cent. and various grid voltages (see Fig. 1).

Using a plate potential of 150 volts and a grid bias of 3 volts, the grid potential input should not exceed 0.5 volt lest the distortion factor should exceed 4 per cent. It will be seen from the curves that this valve gives a mean amplification of 30. To the given grid potential input there corresponds an alternating plate potential of 15 volts amplitude, which is about all that can be

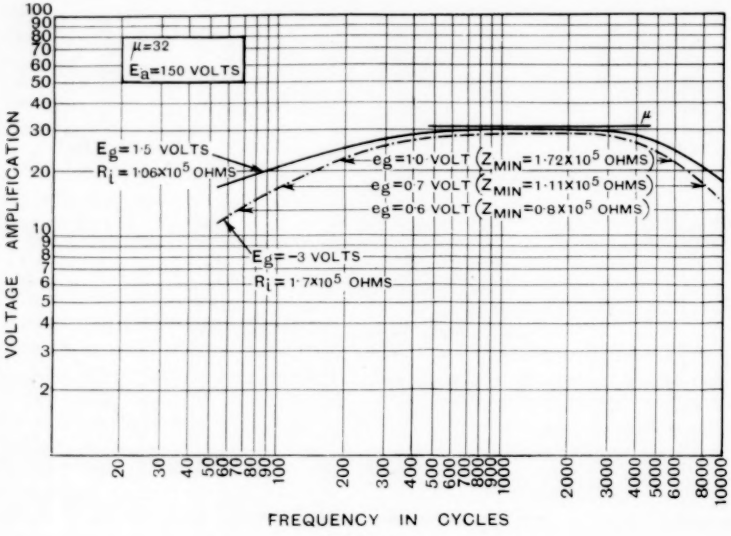


Fig. 3.

factor for a given working point on the characteristic. The maximum value of the grid potential input is seen from formula (4) to be

$$e_{g\ max.} = K_v \frac{4.S}{\frac{\partial S}{\partial E_g} \cdot \frac{R_i^2}{|Z+R_i|^2}} \qquad (5)$$

If the maximum grid-potential input is calculated for static conditions and special care is taken that it does not exceed the value derived from equation (5), the distortion factor can never exceed the critical value, because the *dynamic working characteristic* is always less curved than the static valve characteristic, assuming the same working point in each case. For an ordinary valve used in a resistance coupled amplifier the maximum grid potential input has been utilised in the power stage without exceeding the distortion factor of 4 to 6 per cent. It need not be pointed out that in using amplifiers with the same distortion factor one should prefer, of course, always that one which gives the largest voltage amplification, since it applies a larger output potential to the grid of the next valve. The distortion factor might be expressed by the formula

$$K_v = \frac{\partial E_a}{e_a} \qquad \ldots \qquad \ldots \quad (6)$$

assuming the alternating plate potential to be fixed at that value which just starts to overload the following valve.

It has been mentioned above that when a resistance is connected in the plate-circuit the distortion will always be smaller than

expected from the static valve characteristic. In choke-coupled amplifiers the valve impedance at the ordinary grid bias and plate potential is given and not the value of the plate-circuit impedance Z, which is dependent on the frequency. In this connection it is interesting to calculate how large the minimum value of the plate-circuit reactance has to be, in order to amplify under given circumstances a certain grid potential input with the critical distortion factor. This minimum value of $|Z|$ follows from a simple transforming of equation (4)

$$|Z| = R_i \left\{ \sqrt{\frac{\delta S}{\delta E_g} \cdot \frac{D \cdot R_i \cdot e_g}{4 \cdot K_v} - 1} \right\} \qquad (7)^*$$

As a practical example, Fig. 3 shows the results for a choke-coupled amplifier with data according to Figs. 1 and 2. The critical minimum value of $|Z|$ has been calculated for various grid potentials and a distortion factor of 4 per cent. This amplifier is fairly independent of all grid potential variations up to 0.6 volt within the range of the respective frequencies. A grid-potential input of 0.7 volt, for example, will be amplified only within the range of 110-8,500 cycles sufficiently free of amplitude distortions. The dimensions and constants of this amplifier, which is, by the way, suitable for many purposes, are given in Figs. 1, 2, A, B, and 3.

It is worth while to draw attention in this connection to the high inductance value of the choke. To explain the exceptionally large value it should be added that the plate current of the valve employed, which had a large amplification factor, was very low and the choke coil itself was only weakly pre-magnetised in spite of the high number of windings. Obviously, the same conditions are given in transformer-coupled amplifiers using valves with high voltage amplification factor. To get a clear conception of the distortion it is better to express the distortion factor by the ratio of currents than by that of voltages. Thus the detection effect can be expressed in terms of the amplitude I_a of the alternating plate current, which should correspond either to the grid-potential input or the alternating plate potential, by the following relation

$$K_v = \frac{\delta I_a}{I_a} \qquad \ldots \qquad \ldots \qquad (8)$$

This formula is specially useful in the case of power stages. The amplitude of the plate current might at the utmost become equal to the ordinary current I_a which flows when the transmission is interrupted. From this definition of the distortion-factor one obtains the following value for the maximum fluctuation of the plate current.

$$I_a = K_v . I_o \qquad \ldots \qquad \ldots \qquad (9)$$

From this equation, for example, it can be inferred that the fluctuation of a sufficiently inertialess ammeter in the plate circuit of a power valve should be lower than 0.05 of the indicated value, in order to obtain good reception on a good loudspeaker of the diaphragm type.

On account of the large amplification usually obtained in modern low-frequency amplifiers the amplitude of the grid potential in the first stages is usually smaller than 0.05 volt. For this reason there is in the first stages no perceptible amplitude distortion (due to curvature of the working characteristic), the principal problem here being only to bring about as high an amplification as possible in the required range of frequencies.

* It should be noted that with choke coupling $|Z+R_i|^2 = Z^2 + R_i^2$. It should also be noted that $D = 1/\mu$ and therefore $DSR_i = 1$.

Further Notes on the Reflex Voltmeter.

By W. B. Medlam, B.Sc., A.M.I.E.E., and U. A. Oschwald, B.A.

Description.

THE reflex type of voltmeter was suggested by the authors* to overcome the disadvantages of the ordinary types that they have a very restricted range, and that their scales are far from being linear. The scale of a reflex voltmeter may be made linear within about 2 or 3 per cent. over 80 per cent. of its range, and any range may be obtained, with a moderate H.T. voltage, up to about 50 volts R.M.S. without the use of any grid bias cells. The essential connections of the voltmeter are shown in Fig. 1. It will be seen that a high resistance,

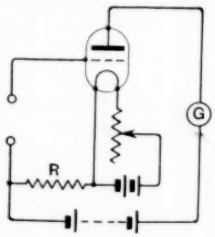


Fig. 1. *Essential connections of reflex voltmeter.*

R, is connected between the negative ends of the H.T. and L.T. supplies. The action of this high resistance is two-fold. As it is connected in the plate circuit, and carries the plate current, there will be a voltage drop across it. Thus the plate potential is reduced as the current is increased. The effect of this is to make the scale of the indicating instrument in the plate circuit less open at the higher readings, and hence more linear. As the resistance is also connected in the grid circuit the P.D. across it, due to the anode current through it, acts as a negative grid bias. Thus the resistance provides automatically a negative grid bias proportional to the input voltage on the grid. The first effect of this action is to increase very greatly the amplitude of A.C. voltages which may be applied to the grid before grid current occurs. It may be noted that this increased range is obtained without sacrifice of sensitivity with low inputs as the bias falls with the input. The second effect of the action of the resistance in the grid circuit is to slow down still further the rate of increase in plate current with increased A.C. input to the grid, leading to a further improvement in the linearity of the scale of the instrument.

Effect of Capacity across the Resistance.

The presence or absence of capacity across R will make a great difference to the calibration of the voltmeter.* If there is no capacity the plate current through R will be pulsating at the frequency of the input voltage, and the grid bias due to the P.D. across R will vary in unison with the outline of the input voltage. If R is shunted by a large capacity the P.D. across it will be practically steady, and the grid bias will vary little—if at all—throughout the cycle.

If the voltmeter is used without any shunt capacity other than the self-capacity of the resistance a linear calibration appears to be obtainable rather more easily, but the calibration will vary with the frequency, and there will be a loading effect on the input circuit due to the resistance.

If a shunt capacity is used of such a value that its reactance at any frequency on which the voltmeter is to be used is small compared with the ohmic resistance R, then the calibration of the voltmeter will be independent of frequency. For example, with resistances down to 100,000 ohms, a capacity of $2\mu F$ would be safe at any frequency down to 50 cycles. The capacity, in addition, cuts out entirely the loading effect of R on the input.

From the above it appears preferable to calibrate and use the voltmeter with the resistance shunted by a condenser.

*E.W. & W.E., November, 1926.

* See also *Note sur le Voltmètre Thermoionique*, by M. Jean Marique, in *Q.T.C.*, Nos. 2 and 3.

Provision of Bias.

The negative grid bias necessary for the voltmeter may be provided partly by cells and partly by the P.D. on the resistance, or it may be provided entirely by the resistance. The disadvantage of the latter method is that the instrument deflection with no input voltage will probably be large, and it will be necessary either to "set up" the pointer, or to balance out this initial current electrically. A small initial bias helps to reduce this current, but if this bias is large the lower part of the scale is adversely affected. The authors' personal preference is to use the voltmeter without any grid cells at all.

Values of Resistance and H.T.

For any given resistance there will be a least value of H.T. which can be used.

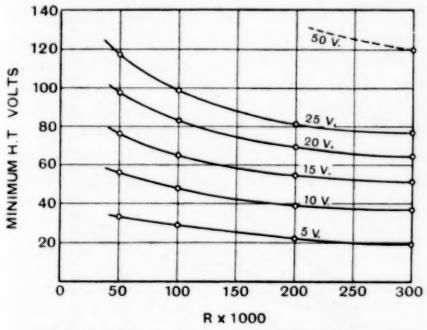


Fig. 2. *Variation of minimum H.T. with reflex resistance for various voltmeter ranges, with DE5 valve.*

This value depends on the type of valve and on the range of the voltmeter. For example, suppose a voltmeter is required to read up to 25 R.M.S. volts. Assuming a sine wave, the peak input will be 35.3 volts, and the negative bias with full input should be not less than about 36 volts. If the resistance is 100,000 ohms, and this has to supply the whole of the bias, the anode current must not be less than $36 \times 10^6/10^5 = 360$ microamps with the maximum input. It is necessary to raise the H.T. until this current is obtained.

The relation between this minimum H.T. and the value of R is shown in Figs. 2 and 3 for two different types of valve, and for the voltmeter ranges (R.M.S. volts for full scale reading) shown on the curves. It will be seen that for a given range and given resistance, the H.T. required for the DE5

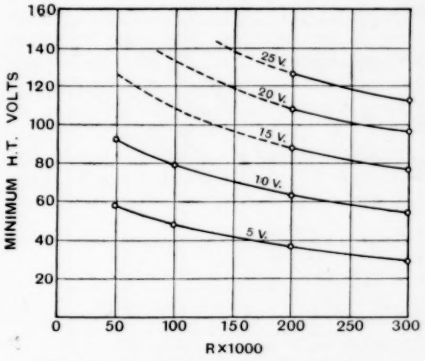


Fig. 3. *Variation of minimum H.T. with reflex resistance for various voltmeter ranges with R-type valve.*

valve—owing to its greater emission—is much less, in all cases, than for the R-type valve. If the H.T. is limited to 120 volts a voltmeter range of 50 volts is practicable for the DE5, against only 25 volts for the bright valve. Secondly, for any given range, the H.T. becomes less as the resistance is increased, but while there is little to be

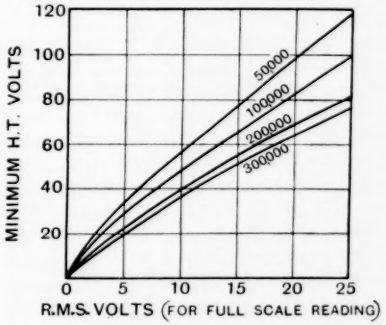


Fig. 4. *Variation of minimum H.T. with voltmeter range for various reflex resistances, with DE5 valve.*

gained in this respect by increasing the resistance above 200,000 ohms for the DE5, the value for the R valve may exceed 300,000 ohms, and thus pull down the H.T. by another 10 volts or so.

The working conditions for intermediate ranges may be determined from the curves in Figs. 4 and 5, which have been deduced from Figs. 2 and 3.

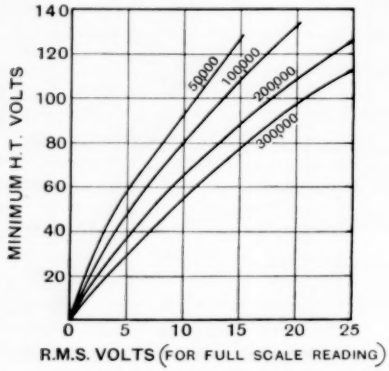


Fig. 5. *Variation of minimum H.T. with voltmeter range for various reflex resistances, with R-type valve.*

Calibrations.

Specimen calibration curves are given in Figs. 6 and 7 for a DE5 valve, for various voltmeter ranges and resistance values. The curves in Fig. 6 all refer to a 10-volt range, with the values of resistance and H.T. given in Table I.

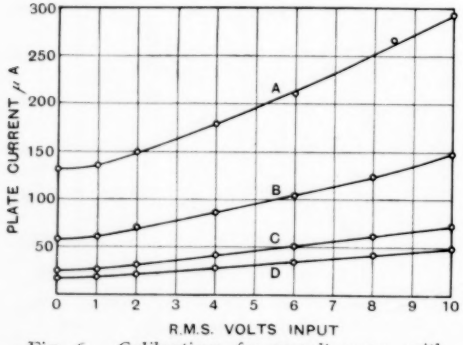


Fig. 6. *Calibrations for 10-volt range, with DE5 valve.*

The curvature of all these calibrations is very small from 2 volts upwards.

In Fig. 7, curve *E* is a calibration for a 25-volt range with $R = 100{,}000$ ohms, and H.T.=100 volts, while curve *F* refers to the same range with $R=300{,}000$ ohms, and H.T.=80 volts. Curve *G* is a calibration for a 50-volt range, with $R= 300{,}000$ ohms and H.T.=120 volts. These calibrations may be considered linear over 80 per cent. of the scale.

In all the above calibrations the whole of the grid bias is provided automatically by the P.D. on the resistance, and the grid bias conditions are safe at every point for the peak of the input voltage, assuming a sine wave. The H.T. used is, in each case, the nearest convenient value above the minimum obtained from Fig. 2 (or Fig. 4).

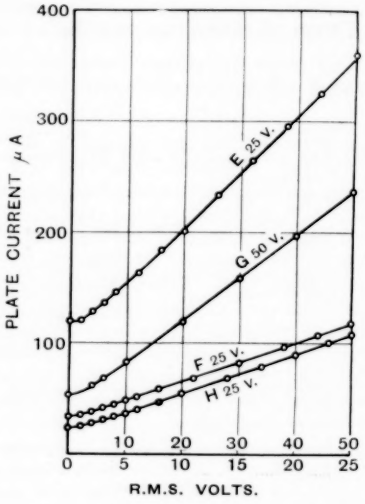


Fig. 7. *Calibrations for 25- and 50-volt ranges, with DE5 valve.*

Graphical methods of calculating the calibrations of reflex voltmeters have been developed by M. Jean Marique in a Belgian wireless review.*

TABLE I.

Curve	A	B	C	D
Resistance	50,000	100,000	200,000	300,000
H.T.	60	50	40	40

* *Loc. cit.*

Initial Current Balance.

It will be noted from the calibrations given above that the initial deflection with zero input is such an appreciable proportion of the full scale deflections that it is advisable to adopt means to reduce or to eliminate its effect. One method is to apply a small initial bias by means of cells. The effect of this is illustrated in Fig. 7, in which curve *H* is a calibration taken with the same resistance and H.T. as for curve *F* but with an initial bias of —4 volts. The calibrations are practically parallel throughout: the initial bias produces the same reduction in full scale current as in the current with no input, but the ratio of these currents is, of course, greater for the lower curve. The useful length of scale depends on this ratio, and is somewhat greater when initial bias is used. A mechanical method of eliminating the initial current is to " set up " the pointer, by means of the zero adjustment, until it comes to the zero of the scale when the filament emission is correct with zero input. This method must be used with care as, with too large a set up, the pointer may be bent when the instrument is suddenly switched off from full scale reading. Another disadvantage of this method is given below.

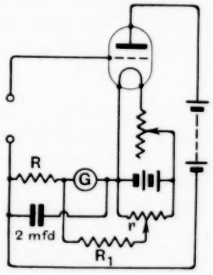


Fig. 8. *Reflex voltmeter with initial current balance.*

The usual electrical method is illustrated in Fig. 8, in which r represents a potential divider connected across the filament battery, and R_1 a high resistance to minimise the shunting effect of r across the galvanometer. The potential divider may be of 300-ohm resistance, and R_1 may have a value between, say, 10,000 and 50,000 ohms for galvanometer resistances up to 1,000 ohms.

If R_1 is too low the shunting effect of it in series with a portion of the potential divider may vary appreciably with the position of the slider. The resistance in the circuit due to the potential divider may vary from zero, with the slider at either end to a maximum value of 75 ohms with the slider in its mid position on a 300-ohm resistance. If R_1 is too high insufficient current may be obtained in the local circuit to balance out the plate current. In practice it is preferable to make R_1 nearer its upper rather than its lower limit as this gives finer control on r of the balance current.

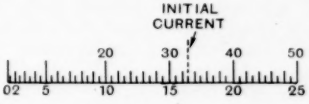


Fig. 9. *Scale of reflex voltmeter for 25- and 50-volt ranges.*

Two Range Voltmeter.

As, in this reflex voltmeter, the plate current with maximum input voltage is determined by the value of R and the minimum P.D. it is necessary to develop across it according to the input voltage, it will be necessary, in general, to shunt the galvanometer to bring the reading with this current to the top of the scale. It is convenient to add an additional shunt which will increase the current through the instrument so that full scale reading is obtained with half the maximum input—thus giving a second voltage range of half the maximum range. As the calibrations are so nearly linear the same scale may be used for both ranges with little sacrifice of accuracy.

Consider, for example, the 50-volt calibration shown by curve *G* in Fig. 7. We may arrange a shunt such that with 25 volts input the required current of 139μA —or better, the increase of 85μA from the " zero " of 54μA when the initial current is balanced—gives full scale reading. The scale may then be equally divided from 25 volts at the top down to 10 volts, the divisions below 10 volts becoming smaller. To read inputs between 25 and 50 volts, the shunt may be tapped to reduce the current through the instrument until its reading with 50 volts input is the same as for 25 volts on the lower range. The

multiplying factor of 2 will then hold fairly correctly down to the 10-volt division. This scale is shown in Fig. 9.

The initial current "zero" (54μA in this case) must be marked on the scale to enable the correct filament emission to be obtained when the voltmeter is first put into operation.

It may be pointed out that with the electrical method of balancing the initial current (Fig. 8) the balance is unaffected by shunting the galvanometer, or by changing the shunt, so that no readjustment is necessary when changing the range of the voltmeter; but with the mechanical method the set up must be altered each time the range is changed.

Operation of Voltmeter.

The method of putting the voltmeter into service is as follows: See that the current balance is switched off, that the *low* range shunt is in action if the voltmeter is of the two range type, that the H.T. is of correct value, and that there is a closed grid to filament circuit. Then switch on the filament and increase the plate current until the pointer comes to the initial current line on the scale. Leave the voltmeter for five minutes or so, then readjust the filament current if any change has occurred. Continue readjustments until constant conditions are obtained then switch on the balancer and adjust until the pointer is moved back to the true zero of the scale. The voltmeter is then ready for service.

Voltmeter with Broken Input Circuit.

The connections may be arranged so that the voltmeter is unaffected by D.C. voltages across its input by inserting a grid condenser and leak as shown in Fig. 10. This diagram shows the complete connections with a current balance and tapped shunt for two ranges.

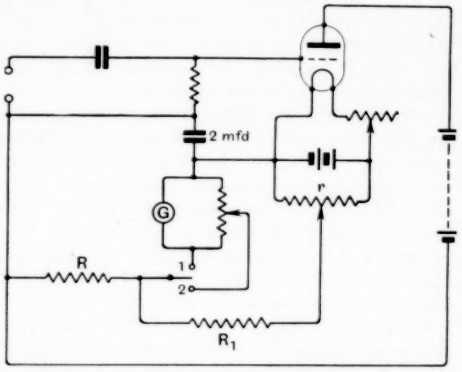


Fig. 10. *Two-range reflex voltmeter with current balance and grid condenser and leak.*

Tetrode Voltmeter.

Further applications of the reflex principle to four-electrode valves have been suggested and some experimental results given, in *Q.T.C.**

* *Loc. cit.*

A New Method of Using Resistance Amplification with Screened Grid Valves.

By John J. Dowling, M.A., F.Inst.P.

IN view of their high impedance "screened grid" valves have not hitherto been employed to any great extent except in tuned high-frequency circuits. It is the purpose of this note to describe a method whereby these valves may be used to obtain really enormous amplifications in aperiodic circuits of the resistance coupled type.

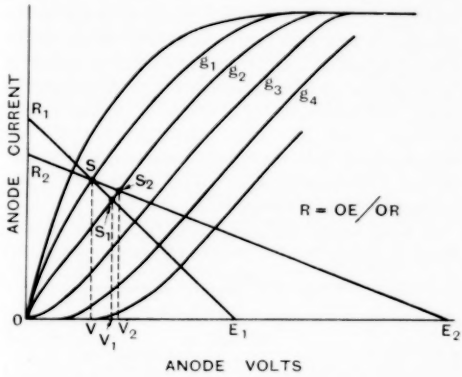


Fig. 1.

Consider in the first place the well-known graphic representation of amplification in a triode resistance amplifier stage. In Fig. 1, the curves g represent the different anode current-voltage curves corresponding to equal steps (u) of grid voltage. If E_1 is the voltage of the H.T. battery and E_1R_1 is drawn so that $E_1O/OR_1 = R_1$, the series resistance to be used, this line cuts the curves in such points as SS_1. For a grid voltage g_1 the actual anode voltage is OV. If the grid voltage is made more negative (g_2), the intersection S moves to S_1 and the anode voltage *rises* to OV_1. Thus the voltage amplification is

$$\frac{VV_1}{g_1 - g_2} = \frac{VV_1}{u}.$$

Let a higher resistance R_2 be used; a higher battery voltage will be required in order that the line E_2R_2 may still cut across the curves where they are straight and equispaced (this is desirable to avoid distortion). The amplification ratio will now be

$$\frac{V - V_2}{u},$$

which is greater than before.

The maximum (theoretical) limit is attained when ER is horizontal: a condition corresponding to an *infinite* resistance R, which is naturally impossible of actual attainment.

Fig. 2 illustrates, roughly, the contours of the same curves for a screened plate valve. An actual test will show that the amplification ratios for either of the possible "resistance lines" ES and ET are much less than would be obtained with an appropriate *triode resistance* combination working with the same H.T. voltage.

Consider now the part of the curves, between XY, *where they slope downwards*. In Fig. 3 these portions are drawn for two

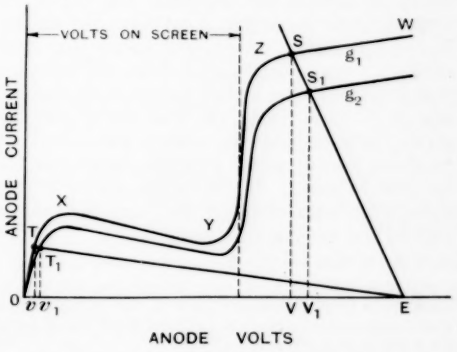


Fig. 2.

curves corresponding to a very small difference in grid voltage (say 2/100 volt). The "resistance line" ER here cuts very obliquely across the curves, although its actual slope is quite steep and corresponds

to a resistance R of moderate value. For the small change in grid voltage from g to g_1 a very great alteration occurs in the anode voltage $(V_1 - V)$. We thus have a condition capable of yielding enormous amplification.*

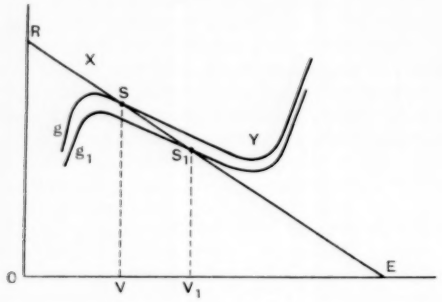


Fig. 3.

It is unfortunate that the range of anode voltage change available for the process lies between XY, which is in practice about 30 volts. This restricts the application of this method to the magnification of minute voltage fluctuations of the order of hundredths of a volt. Nevertheless it should prove of value in certain cases. Probably valves of the dynatron type could be designed to give a more extended range.

To satisfy myself that the above process could be carried out and that the hoped for results could be attained without instability in the apparatus, an experiment on the lines of Fig. 4 was performed. The valve was a Marconi S625, the screen grid voltage 80 and the H.T. 120 volts. R was made 180,000 ohms, which was the value estimated to produce the greatest possible stable amplification when E is 120 volts and *the grid voltage adjusted* so that the line ER intersected the curves as shown in Fig. 3. This grid voltage adjustment was made by a potential divider giving steps each of .02 volt. The electrostatic voltmeter was an Ayrton Mather instrument with an 80-volt battery (not shown) in series to bring the deflection to the most sensitive part of the scale. The measured amplification was almost exactly what was expected from the values of the R and E chosen, and the contours of the curves as previously plotted, namely, 150 *fold*. With greater values of the resistance the setting becomes unstable, but with smaller ones a lower amplification is obtainable if the H.T. voltage E be reduced or the mean grid voltage raised to suit.

As will be readily apparent on consideration of the contour of the curves (Figs. 2 and 3), provided that the resistance R chosen is not too large (nor the value of E) the only adjustment required in practice is to vary the grid potential by a potentiometer until the valve is operating at such a grid voltage that the characteristic curves are intersected by the "resistance line" ER within the region XY. The method is thus quite simple to carry into practice.

I may point out in conclusion one drawback. Usually the parts XY of the various

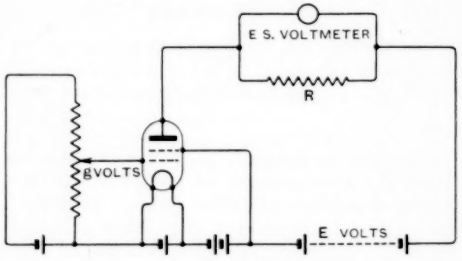


Fig. 4.

curves are not exactly parallel. This may cause unequal amplification for weak and strong signals. The effect of this in audio-frequency amplifiers may be unpleasing to the ear for telephony, but it is of little importance in telegraphic work.

* Unlike the ordinary case of resistance amplification there is no *theoretical* limit to the amplification ratio obtainable, since the process does not depend on a valve amplification factor.

The Accuracy and Calibration Permanence of Variable Air Condensers for Precision Wavemeters.

By W. H. F. Griffiths, A.M.I.E.E., Mem.I.R.E.

(*Concluded from page 24 of January issue.*)

A Serious Defect.

In this simple construction an important defect has, for simplicity, been ignored. It will be seen that a relatively large capacity will be present between the portions of the surfaces of adjacent moving plates *IP* which are not interleaved—a capacity which will become larger as the actual capacity of the complete condenser is reduced. This inter-moving plate capacity militates against the

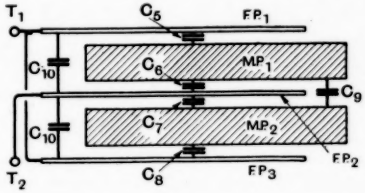
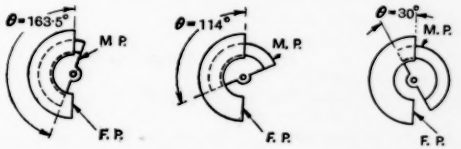


Fig. 9.

scheme of " constancy of capacity irrespective of the lateral positions of the moving plates " as the diagram (Fig. 9) of the resultant electrical system of three fixed plates and two moving plates will show. Fig. 10 is a simplification of this diagram and by an inspection of this it will be seen that whilst the moving plates MP are revolving truly and exactly midway between the adjacent fixed plates the series capacities C_5 and C_6 are equal and C_7 and C_8 are equal, the two moving plates MP_1 and MP_2 being, therefore, equipotential conductors. Under these conditions the interplate capacity C_9, whatever its value, does not contribute to the resultant capacity of the complete condenser system. If, however, the two moving plates, for some reason, fall slightly the capacities C_6 and C_8 are increased, and although the resultant capacity of the condenser system will not be affected by this movement if the capacity C_9 is zero the constancy will be impaired in practice as this latter capacity is of a very appreciable order. Even so, the constancy of a condenser built on this " series complementary gap " principle is greater than that of the ordinary " parallel complementary gap " condenser as can be shown by taking, as an example, the simple variable condenser of three fixed plates and two moving plates of Fig. 9.

The Extent of the Errors introduced by the Capacity between adjacent Moving Plates.

Since the effect of the inter-moving plate capacity C_9 becomes increasingly serious as the capacity of the condenser is reduced, it is necessary to determine the change of capacity due to axial displacement of moving plates for various angular positions " θ " of the latter; thus three cases have been chosen :—



Case I. Case II. Case III.

(*I*) *Moving plates interleaved with fixed plates throughout an angle* " θ " *of* 163.5 *degrees,* i.e. *nearly maximum capacity* (180°).

(*II*) *Moving plates interleaved with fixed plates throughout an angle* " θ " *of* 114 *degrees.*

(*III*) *Moving plates interleaved with fixed plates throughout an angle of only* 30 *degrees.*

In order to make the example quantitative the capacity C_5, when equal to C_6, for the full 180 degrees of intercalation will be taken as 109$\mu\mu$F, and the capacity C_9 between adjacent moving plates at the minimum setting of the condenser (zero intercalation), 54.5$\mu\mu$F. The ratio between

these capacities has been purposely made to represent the worst possible condition when the fixed plate thickness is zero.

The capacities C_5 C_6 C_7 C_8 and the capacity C_9 are determined for the three cases thus :—

CASE I. $\theta=163.5°$

$$C_5=C_6=C_7=C_8=\frac{dC}{d\theta}\times\theta=\frac{109}{180}\times 163.5$$
$$=100\mu\mu\text{F approx.}$$

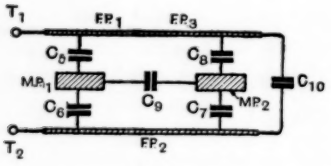


Fig. 10.

$$C_9=\frac{dC'}{d\theta}\times(180-\theta)=\frac{54.5}{180}\times(180-163.5)$$
$$=5\mu\mu\text{F.}$$

CASE II. $\theta=114°$.

$$C_5=C_6=C_7=C_8=\frac{109}{180}\times 114$$
$$=70\mu\mu\text{F approx.}$$

$$C_9=\frac{54.5}{180}\times(180-114)=20\mu\mu\text{F.}$$

CASE III. $\theta=30°$

$$C_5=C_6=C_7=C_8=\frac{109}{180}\times 30$$
$$=18\mu\mu\text{F approx.}$$

$$C_9=\frac{54.5}{180}\times(180-30)=45\mu\mu\text{F approx.}$$

The capacity C_{10}, although not constant with all values of θ, remains constant for any given value of θ, being unaffected by axial displacement of the moving plate system and can, therefore, be ignored in calculating the capacity *changes* due to this mechanical imperfection. Values for C_{10} will, however, be required later in order to express the changes of capacity as percentages of the total capacity of the complete condenser.

The five remaining elementary capacities may be redrawn as a bridge network, as shown in Fig. 11.

In the ideal condition when $C_5=C_6=C_7=C_8$ the resultant capacity C_R between T_1 and T_2 is simply equal to one of these elementary capacities, but when, due to an axial displacement of the moving plate system,

$$C_6=C_8>C_5=C_7$$

the resultant capacity C_R is best determined by adopting Maxwell's theory of networks in which I_1, I_2 and I_3, of Fig. 11, are hypothetical cyclic currents.

Employing these cyclic currents three simple equations may be formed :—

$$\frac{1}{\omega}\left(\frac{1}{C_7}+\frac{1}{C_8}\right)I_1-\frac{1}{\omega}\left(\frac{1}{C_7}\right)I_2-\frac{1}{\omega}\left(\frac{1}{C_8}\right)I_3=E \quad (1)$$

$$-\frac{1}{\omega}\left(\frac{1}{C_7}\right)I_1+\frac{1}{\omega}\left(\frac{1}{C_6}+\frac{1}{C_7}+\frac{1}{C_9}\right)I_2-\frac{1}{\omega}\left(\frac{1}{C_9}\right)I_3=0 \quad (2)$$

$$-\frac{1}{\omega}\left(\frac{1}{C_8}\right)I_1-\frac{1}{\omega}\left(\frac{1}{C_9}\right)I_2+\frac{1}{\omega}\left(\frac{1}{C_5}+\frac{1}{C_8}+\frac{1}{C_9}\right)I_3=0 \quad (3)$$

These equations can be simplified by eliminating the angular velocity thus :—

$$\left(\frac{1}{C_7}+\frac{1}{C_8}\right)I_1-\left(\frac{1}{C_7}\right)I_2-\left(\frac{1}{C_8}\right)I_3=\omega E \ldots \quad (4)$$

$$-\left(\frac{1}{C_7}\right)I_1+\left(\frac{1}{C_6}+\frac{1}{C_7}+\frac{1}{C_9}\right)I_2-\left(\frac{1}{C_9}\right)I_3=0 \quad (5)$$

$$-\left(\frac{1}{C_8}\right)I_1-\left(\frac{1}{C_9}\right)I_2+\left(\frac{1}{C_5}+\frac{1}{C_8}+\frac{1}{C_9}\right)I_3=0 \quad (6)$$

from which I_1 can easily be found and the

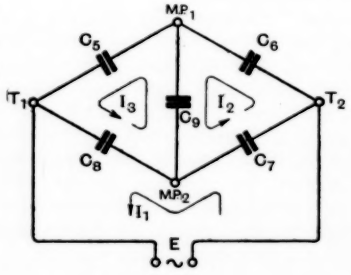


Fig. 11.

resultant capacity

$$C_R=\frac{I_1}{\omega E}$$

and by making ωE equal to unity C_R is directly obtained because

$$C_R=I_1$$

The lowest value of C_R is, in each case, that obtained when all four elementary

capacities are equal

$$C_R = C_5$$

the greatest value of C_R is, in each case that

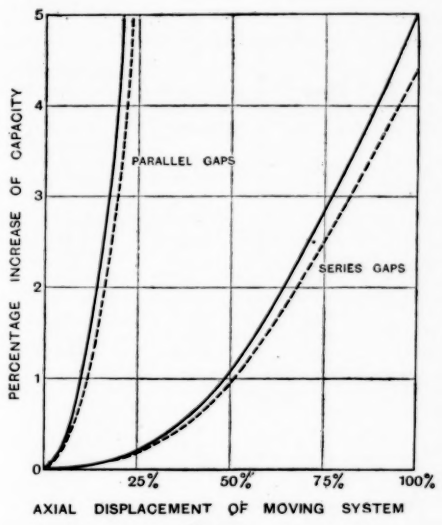


Fig. 12.

reached when

$$C_6 = C_8 = \infty$$

then C_5 and C_7 are reduced to 0.5 of their original mid-position values and the resultant capacity becomes

$$C_5 + C_7 + C_9$$

or, in other words, the capacity of the whole system cannot, even for the maximum axial displacement of moving system, increase by more than the amount of C_9.

In addition to these two limiting values of C_R, other intermediate values have been computed, by forming and solving three equations, (4), (5) and (6), for each of the three cases of the example and the results are given in the Tabulation A below and are shown in the full line curves of Figs. 12, 13 and 14. These curves show the post-calibration capacity increase due to an axial displacement of the moving plates relative to the fixed plates assuming that all dielectric gaps have been equalised at the time of calibration. In the same figures are given, for comparison, curves showing the corresponding capacity changes which would be experienced under the same conditions if the adjacent dielectric gaps were in parallel instead of in series. It will be observed that, although the possibility of capacity change becomes more serious for lower capacity settings, it is always less serious than in ordinary parallel gap condensers, for which the theoretical limit of infinity capacity is reached (although not smoothly) by a short-circuiting of the moving and fixed plate systems.

The tabulated figures below and the full

TABULATION A.

Case.	θ degrees.	C_9 $\mu\mu$F.	Axial displacement of moving system. %	$C_5 = C_7$ $\mu\mu$F.	$C_6 = C_8$ $\mu\mu$F.	C_R $\mu\mu$F.	Increase of C_R %	Corresponding increase of capacity of ordinary condenser. %
I.	163.5	5	0	100	100	100	0	0
			25	80	133.3	100.2	0.2	6.7
			54	65	217	101.3	1.3	40
			100	50	∞	105	5.0	∞
II.	114	20	0	70	70	70	0	0
			27.5	55	96.4	70.8	1.2	8
			55.5	45	157.3	75.6	8.0	45
			100	35	∞	90	28	∞
III.	30	45	0	18	18	18	0	0
			28	14	25.2	19	5.5	8.5
			64	11	50	25.3	40	70
			100	9	∞	63	250	∞

line curves of Figs. 12, 13 and 14 need correction for varying values of minimum or residual capacity. In the case of the ordinary parallel gap condenser the per-

denser is paralleled with the variable condenser for the purpose of range limiting. In the case of the series gap condenser the residual capacity is *always*, due to its design,

TABULATION B.

Case.	θ degrees	Axial displacement of moving system. %	C_{10} unaffected by axial displacement. $\mu\mu$F.	C_R from Tabulation A. $\mu\mu$F.	Total capacity C_R+C_{10} $\mu\mu$F.	Increase of total capacity. %	Corresponding increase of capacity of ordinary condenser. %
I.	163.5	0	13	100	113	0	0
		25		100.2	113.2	0.18	5.5
		54		101.3	114.3	1.15	25
		100		105	118.0	4.4	∞
II.	114	0	19	70	89	0	0
		27.5		70.8	89.8	0.9	7
		55.5		75.6	94.6	6.3	30
		100		90	109	22.5	∞
III.	30	0	29	18	47	0	0
		28		19	48	2.1	3.2
		64		25.3	54.3	15.5	25
		100		63	92	96	∞

centage capacity change corrections are small, due to the low value of residual capacity, but become very appreciable at the lower capacity settings if a fixed value con-

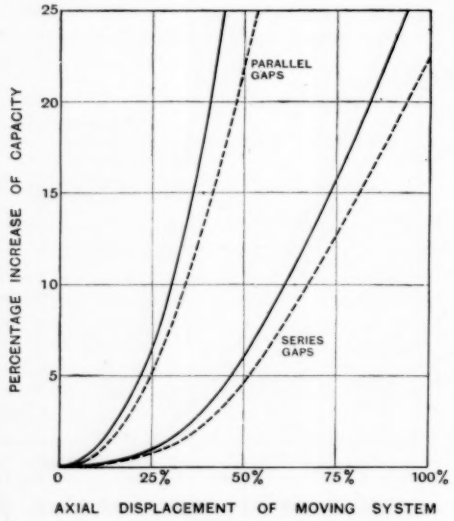


Fig. 13.

an appreciable proportion of the total capacity and corrections therefore become necessary irrespective of independent augmentation of minimum capacity. In order to find the *total* value of capacity at any angle θ it becomes necessary to determine C_{10} as previously mentioned and to do this the moving plate thickness has to be fixed, and this will, in turn, be fixed by the ratio of maximum to minimum capacity.

Assuming therefore a 5 to 1 ratio of effective dielectric gaps :—

$$d_5 = 5(d_3 + d_4)$$

and

$$\frac{dC''}{d\theta} = 0.2\left(\frac{dC}{d\theta}\right)$$

The unaffected capacity C_{10} consists of two parts in parallel :—

(*a*) That between those portions of adjacent fixed plates which are *always* exposed due to their being outside the radius of the moving plates. This component of C_{10} is constant and may be, perhaps, 10 per cent. of the maximum capacity $C_{max.}$; and

(*b*) That between the portions of adjacent

fixed plates which are exposed upon the withdrawal of the moving plates. This component of C_{10} varies with θ and, for the example under consideration, is equal to

$$0.2\frac{dC}{d\theta}(180-\theta)$$

$$\therefore \quad C_{10}=0.1C_{max.}+0.2\frac{dC}{d\theta}(180-\theta)$$

CASE I.

$$C_{10}=(0.1\times 109)+0.2\frac{109}{180}(180-163.5)$$
$$=13\mu\mu F \text{ nearly.}$$

CASE II.

$$C_{10}=(0.1\times 109)+0.2\frac{109}{180}(180-114)$$
$$=19\mu\mu F.$$

CASE III.

$$C_{10}=(0.1\times 109)+0.2\frac{109}{180}(180-30)$$
$$=29\mu\mu F.$$

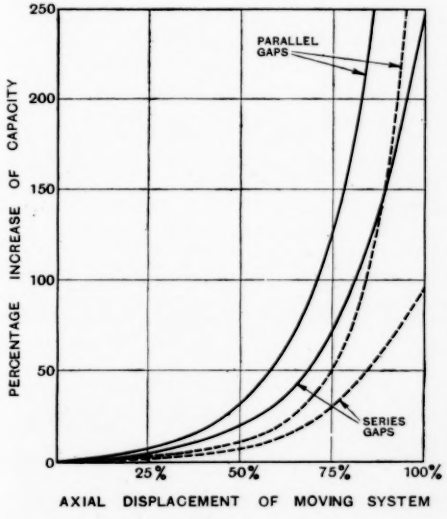


Fig. 14.

These values must be added to those of C_R of Tabulation A in order to obtain the full values of C in each of the three cases. This has been done in Tabulation B, which gives, in the seventh column, the percentage increase of total capacity for various axial displacements of moving system for each of the three cases. In order to provide a fair comparison between this and an ordinary parallel gap condenser the corresponding percentage capacity changes which would occur in such a condenser having the same ratio of maximum to minimum capacity have been computed and tabulated in the

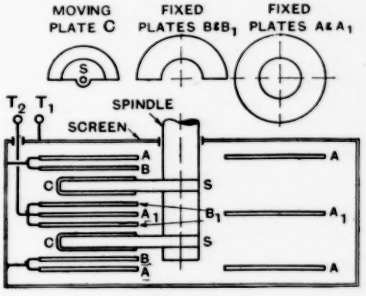


Fig. 15.

final column. These corrected percentage capacity changes which occur in both types of condenser are plotted for the three cases in Figs. 12, 13 and 14 (dotted curves).

These curves have been plotted for exaggerated values of plate displacement in order to include the interesting limiting values, but the actual quantities involved in the case of a variable air condenser of precision quality are those, of course, of Fig. 3 of the first part of the article.

The Elimination of C_9—the Final Design.

In order however, to make full use of this principle of series complementary gaps an entirely different design has to be adopted in which the capacity C_9 is completely eliminated. In this design each intermediate moving plate, in addition to being entirely insulated from all other conductors, is completely screened from the field of all other moving plates. One method of accomplishing this is indicated diagrammatically in the sketches of Figs. 15 and 16.

In Fig. 15 the fixed semi-circular plates BB form the conductors of one terminal system and the exactly similar plates B_1B_1 form the conductors of the other terminal system. These plates are shaped as shown in the detail. The intermediate moving plates CC are formed by semi-circular supports or

vanes of insulating material the outer portions of which are metal encased in order to produce an effective reduction of the gap between two adjacent fixed plates upon its insertion between them. These moving plates may conveniently take the form of silvered glass plates or "Keramot" (loaded ebonite) plates foil coated, or plated. Whatever form these moving plates take, however, the design must be such that dielectric losses in the insulating portions of them is negligible. Since both surfaces of the metal coating of the plates are at the same potential there is no field through the insulating support due to its own conductor but, if this conducting casing does not entirely enclose all the insulating material which is inserted between the adjacent fixed plates, there will be a loss-producing field between the latter. If, on the other hand, the metal coatings of the moving plates extend radially toward the spindle, beyond the boundaries of the fixed plates the constancy destroying intermoving plate capacity will be present. In order that neither of these objectionable features may be introduced, the metal portions of the moving plates are limited radially so as to not quite reach the boundaries of the fixed plates as shown in the sketch, so that field concentration at the inner edges of adjacent moving and fixed plates will prevent an

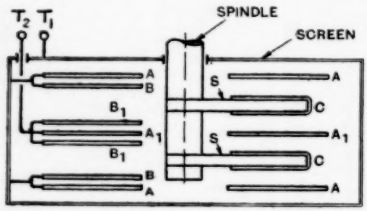


Fig. 16.

appreciable field from passing from B to B_1, through the insulating support S while still eliminating appreciable capacity between adjacent moving plates CC.

It would, perhaps, be safer to employ moving conductors of solid metal such as duralumin fitted to central insulating hubs in order to remove entirely the risk of a change of plate thickness at any point of the plate area since the whole principle depends upon this constancy and uniformity of plate thickness. If a solid metal moving conductor be employed, the only change of dielectric air gap dimensions (apart from a negligibly small change due to the expansion of the metal with temperature—a change for which partial compensation may be made by employing metals with slightly differing coefficients of linear expansion) is that due to a tilting, sagging or twisting of the conductor itself or of its insulating hub.

An imperfection of this nature may be represented by the angle between the planes of moving and fixed conductors; the secant of the angle giving the increase of effective moving plate thickness (normal to the surfaces of the fixed plates) and the cosine of the same angle giving the effective reduction of its radial dimension in a plane parallel to those of the surfaces of the adjacent fixed plates. These two changes tend, respectively, to increase and decrease the capacity at a given scale setting, the resultant tendency to capacity change due to this cause, even for angles of 30′ to 1° being less than 1 part in 10,000.

In order to prevent capacity between these portions of the moving plates which are not enclosed by the fixed plates between which they are rotating, the former are screened from one another by the additional conducting rings AA and A_1 which are connected electrically to appropriate terminal systems as shown. Whatever, therefore, the angular position of a moving plate it is *always* effecting a reduction of the dielectric gap between adjacent and oppositely connected fixed plates and in order that the increase of capacity with rotation of the moving system shall be large the distance between two adjacent semi-circular fixed plates B and B_1 must, of course, be appreciably smaller than that between two adjacent rings A and A_1.

In Figs. 15 and 16 all the semicircular plates have, for simplicity, been shown on the same side of the spindle. In practice, however, it is advisable to balance the moving system by fixing alternate moving plates to the spindle displaced relatively through 180 degrees. This is made possible owing to the fact that the conducting rings A and A_1 completely screen successive condenser elements enabling them to be built up alternately on opposite sides of the spindle. The whole system of fixed conductors, upon the geometrical permanence

of which the electrical permanence of the entire condenser alone depends, is, due to this symmetrical building, made very rigid, it having a large base area for its mounting pillars and its complete conducting rings serving to brace the whole structure at numerous points.

The Capacity Change Obtained.

With this design of condenser it is, of course, impossible to obtain a great capacity change, but this becomes a real advantage when the condenser is to be used for precision wavemeter work, because it renders unnecessary the usual "zero" augmenting

Fig. 17.

capacity which is in this case a fixed value *air* condenser of very rigid construction and having a *large air gap*—the ideal residual capacity.

A usual value for the ratio of maximum to minimum capacity of a good quality variable air condenser (when its metallic screen is connected electrically to its low potential system) is 12 to 1, but, in order to open out the wavelength (or frequency) scale of the instrument and in order that *very small* capacity changes due to disposition of apparatus, leads, near-by conductors and operator may be rendered less important, this ratio is usually limited to about 2 to 1 in precision wavemeter design.

It is possible to obtain a capacity ratio of this order with this new design without increasing unduly the bulk of the condenser.

If d_1, Fig. 17, is the distance between two adjacent complete rings A and A_1;

d_2 is the distance between two adjacent semi-circular fixed plates B and B_1; and

d_3 is the distance between a fixed plate and the adjacent surface of an adjacent moving plate C.

Then the minimum capacity (at 0 degrees)

$$\propto \frac{1}{d_2} + \frac{1}{d_1 - d_2 + 2d_3}$$

and the maximum capacity (at 180 degrees)

$$\propto \frac{1}{d_1} + \frac{1}{2d_3}$$

$$\therefore \text{ Capacity ratio } \frac{C_{180}}{C_0} = \frac{\frac{1}{d_1} + \frac{1}{2d_3}}{\frac{1}{d_2} + \frac{1}{d_1 - d_2 + 2d_3}}$$

$$= \frac{2d_3 + d_1}{2d_1 d_3} \times \frac{d_2 (d_1 - d_2 + 2d_3)}{d_1 + 2d_3}$$

$$= \frac{d_2 (2d_3 + d_1)(d_1 - d_2 + 2d_3)}{2d_1 d_3 (d_1 + 2d_3)}$$

$$= \frac{d_2 (d_1 - d_2 + 2d_3)}{2d_1 d_3}$$

The smallest practicable dimension d_3 is about 40 mils., and assuming this, the expression for capacity ratio becomes:—

$$\frac{d_2 (d_1 - d_2 + 80)}{80 d_1} \quad .. \quad (7)$$

It is obvious that d_2, in order to obtain a good effective gap reduction, must be about six times as great as d_3 and for various values of this order the ratio obtained has

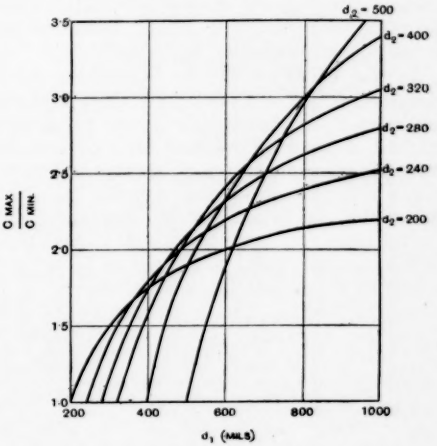


Fig. 18.

been computed from (7) for various values of d_1—the results being shown in the curves of Fig. 18.

From these curves it will be seen that it is not always advisable, from considerations of bulk, to take advantage of the extra

ratio obtained with high values of d_1 and so, choosing a value of 480 mils. for d_1, and a value for d_2 of 240, it is easily seen that this design of condenser has, for a given bulk, a maximum capacity of only

$$0.5\left\{\frac{480+40}{40+40}\right\}$$

that of an ordinary condenser having the same actual dimension of gap between moving and fixed plates; a plate thickness of 0.04 inch being assumed in each case.

Compared with an ordinary condenser, therefore, the product of the plate area and the total depth of bank of plates must be

$$2\left\{\frac{480+40}{40+40}\right\}$$

$= 13$ times greater, for a given capacity; the bank depth must be $\sqrt[3]{13}$ greater and the moving plate radius $\sqrt[3]{13}$ greater.

In practice, however, in order to aim at calibration constancy in an ordinary condenser of precision grade the dielectric air gap would have to be at least three times that of the example of new design given here and so the volume comparison ratio would be reduced from 13 to about 4 due to this —the linear dimension ratio being $\sqrt[3]{4}$.

If the capacity of the condenser to be designed is not of a very high order a greater value of d_1 is permissible (if the capacity is halved, d_1 may be doubled for a given bulk) and a higher value for d_2 chosen. Thus, if for a 0.001μF condenser a value for d_1 of 480 mils. is found to be the maximum permissible, d_2 can be fixed at anything between 240 mils. and 320 mils. without affecting the capacity ratio which would be about 2 to 1. For a condenser of only 0.0005μF capacity d_1 can be increased to 960 mils. without increasing the bulk, the capacity ratio can now be increased to over 3.5 to 1 by increasing d_2 to 500 mils. Series gap variable condensers of this type are, therefore, more easily designed to have large capacity ratios if their actual values are of a lower order.

The Complete Capacity Formula.

The ratios of $C_{max.}/C_{min.}$ given by the curves of Fig. 18 represent the maximum possible ratios obtainable and those obtained in practice may be slightly less due to the constant mutual exposure of the outer portions of adjacent fixed plates if such areas are present in the design to any appreciable extent and it will therefore probably be as well to form a complete expression for the capacity of the condenser at any scale setting.

Let r_1 be the inner radius of both fixed and moving plates,

r_2 be the outer radius of the moving plates,

and r_3 be the outer radius of the fixed plates,

then, expressed in the form $C = NKA/4\pi t$, the capacity of the complete condenser in $\mu\mu$F may be stated as the sum of the six

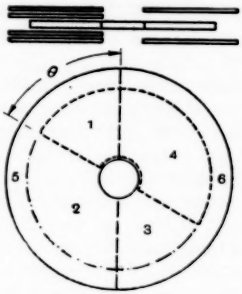


Fig. 19.

capacities corresponding with the numbered areas of Fig. 19.

Thus

$$C = \left\{\frac{1.1A_1}{4\pi(2d_3)} + \frac{1.1A_2}{4\pi d_2} + \frac{1.1A_3}{4\pi d_1} + \frac{1.1A_4}{4\pi(d_1 - d_2 + 2d_3)} + \frac{1.1A_5}{4\pi d_2} + \frac{1.1A_6}{4\pi d_1}\right\} N$$

where

$$A_1 = A_3 = \frac{\pi\theta}{360}(r_2^2 - r_1^2)$$

$$A_2 = A_4 = \frac{\pi(180 - \theta)}{360}\{r_2^2 - r_1^2\}$$

$$A_5 = A_6 = \frac{\pi}{2}(r_3^2 - r_2^2) = \text{constant}$$

and N = number of *moving* plates.

This gives a simplified expression :—

$$\text{Capacity (in } \mu\mu\text{F)} = 7.72 \times 10^{-4}.N\left\{k_1\theta\left(\frac{1}{2d_3}+\frac{1}{d_1}\right)+k_1(180-\theta)\left(\frac{1}{d_2}+\frac{1}{d_1-d_2+2d_3}\right)+180k_2\left(\frac{1}{d_2}+\frac{1}{d_1}\right)\right\} \quad (8)$$

where N = number of *moving* plates

$k_1 = \{r_2^2 - r_1^2\}$

$k_2 = \{r_3^2 - r_2^2\}$

Screening.

In the diagrammatic sketch of Fig. 15 the condenser is shown completely screened. This is, of course, absolutely necessary in a variable condenser of precision quality and no complications are introduced by its use, because the screen may be joined electrically to one fixed plate system the plates of which can therefore be mounted rigidly and simply to the metallic case of the condenser without insulation. The other fixed plate system is mounted on small pieces of silica-quartz or pyrex in order to ensure relative geometrical permanence of the two fixed plate systems. The additional capacity due to the introduction of the screen merely augments still further the residual or "zero" capacity of the condenser and, in the diagram of the simple five plate condenser (Fig. 10), merely results in a slight increase in the value of the elementary capacity C_{10}.

The "Shorting" of Adjacent Plates.

It is seen, therefore, that the complete screened condenser will not have its electrical permanence or law conformity impaired by any irregularity of rotation of the moving plates, nor by any change in their positions axially provided that the bearing is good enough to prevent them from actually touching the fixed plates to which they are adjacent. No alteration of capacity would, of course, take place if a moving plate actually touched one of its adjacent fixed plates throughout the whole of the area of its intercalation, but this could only occur if the moving plate revolved in *exactly* the plane of the fixed plate and in practice this would not be the case. If an axial movement of the moving system were present to such an extent as to permit the touching of a fixed plate by a moving plate, the contact would probably only occur over a portion of the total area of intercalation and the remainder would consist of a thin air gap which would be, in effect, short-circuited by the portion in contact and in this way an alteration of capacity would be effected. Axial movements and rotation irregularities amounting to, say, 10 per cent. or 20 per cent. of the total dielectric air gap will not, in this condenser, produce any change of capacity, whereas similar defects in an ordinary parallel gap condenser would *completely* destroy its calibration.

An Electrical Complication and a Simplification.

An electrical complication which tends to impair very slightly the permanence of the condenser is introduced if the insulating supports or vanes of the intermediate moving plates are mounted on a metal spindle. This spindle will be joined electrically, through its bearing, to the earthy fixed plate system and the complete electrical system can be

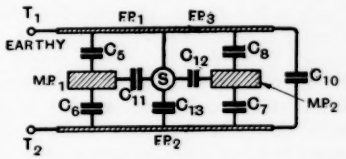


Fig. 20.

represented by redrawing the diagram of Fig. 10 to include the metallic mass S_1 as shown in Fig. 20.

It will be seen that the additional capacity C_{13} merely makes a further contribution to the residual capacity of the condenser but the capacities C_{11} and C_{12} are added to the capacities of C_5 and C_8 respectively. Since these moving plate to spindle capacities are constant they tend to prevent the complementary changes of reactance of the series gaps $C_5 C_6$ and $C_7 C_8$ upon which the whole principle of constancy depends.

These unwanted capacities C_{11} and C_{12}, however, may be made, in practice, small enough to be negligible, and, moreover, if the spindle be made from an insulating material they disappear completely. But it should be noted that any capacity to moving

plates which is, for any given angular position of the moving plates, constant and unaffected by an axial movement of those plates, militates against the permanence of the condenser, and in order to ensure that such unwanted capacities are reduced to negligible proportions the moving plate conductors should be well enclosed by the fixed plate conductors and well away from all other conducting surfaces.

The notes on this special design of variable air condenser would not be complete without mention being made of the incidental simplification of the elimination of a flexible connection or wiping contact to the moving plate system. This feature affords great relief to the condenser designer since, even by exercising the utmost care and ingenuity, it is difficult to obtain, with any one device, all the essential qualities of low and constant effective resistance, low and constant inductance, freedom from noise when used in oscillating circuits, and mechanical reliability with much rotation of moving system.

Conclusion.

In conclusion some idea should, perhaps, be given of the accuracy at which one would aim when designing a sub-standard wavemeter employing this new condenser. In the introduction it was stated that the accuracy should be greater than 1 part in 1000 and with ordinary condensers this is not easy. By employing the new design, however, it is hoped to obtain a frequency accuracy of 1 part in 10,000, corresponding with a capacity inaccuracy of the order 2 parts in 10,000. In addition to the possibilities of inaccuracy already discussed, there are several others which have to be considered carefully before stating a figure of overall accuracy of this order.

For instance, it is just possible that some special means for reading or setting the angular position of the moving system to this degree of accuracy would become necessary. It will, however, be found that a finely divided degree scale of about seven inches radius and having main divisions at 0.5 degree intervals and a 10 division vernier covering 4.5 degrees will be sufficient for the required accuracy of reading, in a condenser having a 2 to 1 capacity ratio.

Another possible cause of an inaccuracy of the order we are now considering is the dimensional change of the scale. A metal scale will be found to have a sufficiently low temperature coefficient of linear expansion to render temperature changes negligible.

There are, of course, numerous possible constructional causes of inaccuracy to be considered—minor mechanical imperfections which were small enough to be negligible in ordinary variable condensers but which now, in the new design, may become limiting factors in view of the fact that the major mechanical imperfections have, by a changed electrical scheme, been rendered unimportant. These are rather outside the scope of the present article and their correction may be left to the ingenuity of the designer and to the conscience of the instrument maker.

There is, however, one other very important aspect to be considered—that of resonance detection. Flatness of tuning must not limit the accuracy of reading and in order that the detection of resonance shall be sufficiently sharp to prevent this the decrement of the whole sub-standard should be not greater than the order 0.006 to 0.008. If the inductances are designed to this efficiency, changes in resonant voltage or current of the order 0.5 per cent. will be obtained by detuning by 2 parts in 10,000 in capacity (1 part in 10,000 in frequency) and these changes are within the limits of simple detection by the two reading method.

In order to keep the *total* decrement down to the required low order it is essential that the contribution to it by the detector shall be not greater than, say, 0.001. This fact demands the utmost care in the choice of a method by which to associate the detector with the simple resonant circuit. Two *direct* methods are frequently employed, the thermo-junction galvanometer for the detection of resonant current or the simple thermionic voltmeter for voltage indication of resonance. Neither of these direct methods can, however, be employed throughout the whole band of useful wavelengths. The thermo-galvanometer method may be safely employed on the longest wavelengths with a heater resistance of 1.0 Ω when the inductance is not less than 20,000μH. With values of inductance less than this a heater of lower resistance must be used, but even with a 0.1 Ω heater the method cannot be employed for values of inductance less than

100μH. It should be noted, also, that with this method, if for greater accuracy the L/C ratio is decreased, the decrement augmentation by the detector is increased.

On the other hand the thermionic voltmeter method may be employed with safety on the ultra-short waveband even if shunted across points having the full potential difference between them. The effective resistance of a thermionic voltmeter is of the order $0.75 \times 10^6\Omega$ and for this value of shunt resistance it will be seen that this method cannot be employed with inductances greater than 25μH without increasing the decrement augmentation beyond the 0.001 limit.

The above figures have been computed taking as a basis a capacity ratio of 2 to 1 for each inductance of the wavemeter and a *minimum* capacity gradually ascending (with wavelength) from 250$\mu\mu$F to 1000 $\mu\mu$F throughout the whole useful waveband.

It will be seen that a gap occurs between 25μH and 100μH (at about 300 metres) where neither of these direct methods should be employed. The gap is small and can be bridged by adhering a little less rigidly to the limits of decrement, but its existence shows that an aperiodic inductively (loosely) coupled detector circuit (crystal and galvanometer) is very desirable, if not essential, for intermediate wavelengths of from, say, 100 to 1000 metres. Above 1000 metres the thermo-galvanometer may be employed with safety if the heater is of low resistance, and below 100 metres the thermionic voltmeter method is satisfactory.

A More Sensitive Method of Resonance Detection.

If the decrement of the circuit exceeds the limit given it will not be possible to obtain readings of the detecting instrument sufficiently accurately to give a frequency accuracy of 1 part in 10,000. Such a reading accuracy will in any case, even with circuits of the lowest possible decrement, be found difficult.

The difficulty is, of course, due to the changes of instrument reading required being very small percentages of the maximum reading at exact resonance. This trouble may be eliminated by employing two galvanometers of different sensitivities in a detecting circuit as shown in Fig. 21.

Resonance is first detected using the indication of the ordinary moving coil *pointer* microammeter G_1 having a range of about 20μA for a full scale deflection. G_2 is a much more sensitive galvanometer of the suspended moving coil *reflecting* type having a sensitivity of about, say, 150 millimetres per μA at a scale distance of one metre. This galvanometer is specially provided with a stop which prevents any deflection of the moving coil from zero in one direction, and a direct current of about

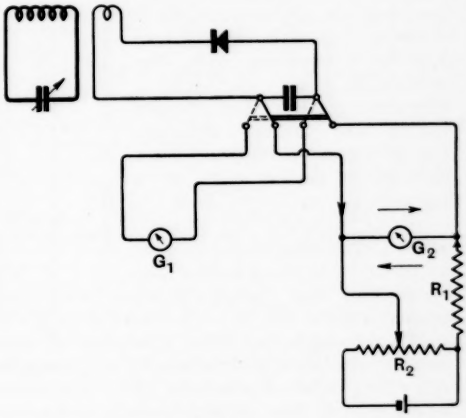


Fig. 21.

say, 10μA is arranged to flow in the galvanometer in the direction which will keep the coil hard up against this stop. The small potential for this purpose is obtained from a single cell and potential divider R_2, the resistance R_1 is required to preserve the correct (critical) resistance of the galvanometer circuit.

If resonance has been obtained on G_1 at about 11μA, upon switching over to G_2 a deflection of 150 millimetres from zero will be obtained for an increase of rectified current from 10μA to 11μA, while currents below 10μA will not deflect the coil from its stopped zero position. The potentials across the galvanometer due to the rectified current and to the initially applied direct current must, of course, be applied so as to oppose. If that due to the rectified current is not sufficient to produce a deflection of G_2 or is sufficient to produce a deflection greater than the scale length, a simple adjustment of the slider of R_2 to give a

smaller or greater "deflection opposing" potential respectively must be made.

The whole arrangement is merely a scheme of magnification which allows the small changes of rectified current about resonance to be spread over the entire scale instead of occupying only a small portion of it; the less sensitive indicator is, of course, necessary in order to initially locate resonance with facility.

By this method a resonance curve of great apparent sharpness can be obtained. Such a curve is shown in Fig. 22 (G_2) for comparison with one obtained using the micro-ammeter (G_1). The points shown are actual readings taken on a circuit of high decrement (about 0.1) at a frequency of 10^6 and a resonant capacity of 400$\mu\mu$F and show a much greater accuracy of reading in the case of G_2 by all falling on a smooth curve.

When employing the two reading method of resonance detection the accuracy of reading will be proportional to the tangents of the angles α and β (*i.e.*, to the "slope" of the curves) if the scale lengths of G_1 and G_2 are of the same order. But the reflecting galvanometer has a scale length usually about ten times that of the pointer instrument and so has an accuracy of detection

$$10\frac{\tan\beta}{\tan\alpha}$$

times that of the latter. This scale length factor should, however, be reduced to about 2.5 on account of the loss of definition and steadiness of the "spot" of a reflecting galvanometer. This magnification factor in the case depicted here is about 20, which increases the accuracy *of detection* from 2.5 parts in 1000 to just over 1 part in 10,000.

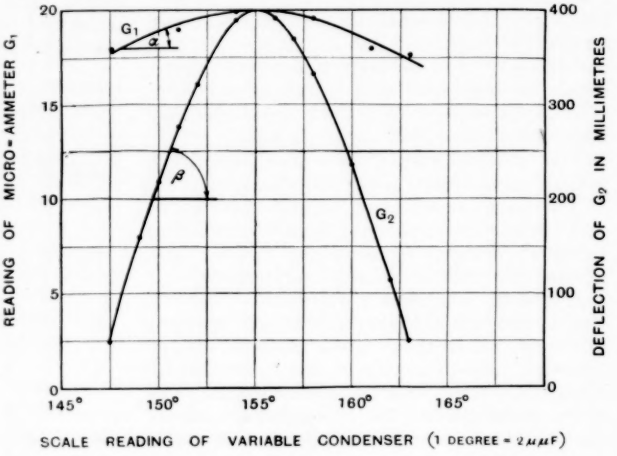


Fig. 22.

A Novel Valve Detector.

By H. J. Neill.

IN the course of experimental work with resistance-coupled speech amplifiers it was found that the valves of the speech amplifier were overloaded, and that the overload could not be accounted for by electro motive forces of audible frequency. From this it appeared that the predetection frequency was present in the speech amplifier and must be eliminated. It was desired to retain a valve detector on account of its reliability and furthermore to use the lower bend of the anode current characteristic for detection. The detector was of course to be coupled by the resistance method to the first speech amplifying valve or else coupled through a filter, or by other means to pass to the detector valve unattenuated all frequencies up to about 12,000 cycles per second. The method of separating the intermediate frequency in a supersonic amplifier from

speech frequencies is known and it can be shown that if the beat frequency is low a two or three-stage filter is necessary to effect adequate separation. Such a filter is not always easy to design and in every case is liable to objection. Up to the present, however, a filter has appeared to be inevitable with supersonic amplifiers working at any frequency above about 300,000 cycles per second.

A perusal of the Western Electric Company's patent specification No. 102,503 which relates to the transmission of one or both side bands only in high frequency telephony, led to the idea that similar methods could be used to eliminate the predetection carrier frequency in the detector.

The characteristic equation of a detector can be written

$$y=f(x)=a+bx+cx^2+dx^3+ex^4+ \quad .. \quad (1)$$

It can easily be shown that the only terms in this expression which are useful to produce the frequency with which a carrier wave has been modulated are those terms having an even number index. Thus the terms cx^2, ex^4 etc., are the only terms useful from the detection point of view. The term bx produces only the original carrier frequency and the two side bands. The cubic term is likewise useless. The problem is therefore to eliminate the terms of odd powers. If we can treat the input in the manner represented by $f(x)+f(-x)$ it is clear that the terms of odd power disappear thus :—

$$\begin{aligned} y' &= f(x)+f(-x) \\ &= 2a+2cx^2+2ex^4+ \quad .. \quad (2) \end{aligned}$$

The characteristic curve of a valve takes the form indicated in equation (1) where x represents the grid voltage and y represents the anode current. Two valves can be used together to fulfil the requirements of equation (2). In order to do this it is necessary to apply the same potential simultaneously to the grids of both valves, but positively to one and negatively to the other. The anodes of the valves must then be connected directly together and y' represents the current in the common lead to the anodes.

A typical circuit is shown in Fig. 1.

It will be seen that the grids of the two valves are connected to opposite ends of the closed oscillatory circuit and the anodes are fed from the battery through a common resistance R_1. The condenser C_1 for coupling the detector to the next valve is connected to the junction of the resistance and anode connections.

It must not be thought that this detector system eliminates all frequencies other than the desired modulation frequency. It does not. Currents of twice modulation frequency and also currents of frequencies higher than

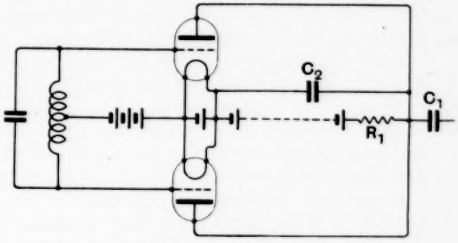


Fig. 1. *A valve detector circuit which requires the use of much less H.T. for a given input voltage than a normal circuit.*

the carrier wave frequency will be present in the resistance R_1. If the fourth power term in equation (2) is not negligible there will also be other harmonics of the modulation frequency. In general, however, if the percentage modulation is not too high the modulation frequency current will predominate. In order to by-pass the high frequencies a condenser C_2 should be connected from the anodes to filaments as shown, but this condenser may in general be reasonably small so as not to by-pass any appreciable quantity of the upper modulation frequencies. In chronic cases of supersonic amplifiers when the beat frequency is very low, such as 30,000 cycles per second, it may be necessary to insert a simple single stage filter between the anodes and the coupling condenser. Although the arrangement has been described as making use of the bend of the anode current characteristic, grid rectification is equally applicable.

The arrangement also has another advantage which is sometimes very useful, namely that it will deal with double the total input voltage that a single detector valve of the same type in the same adjustment can deal with. In certain circumstances this can be very useful. For example, at the author's station in London the amplitude of the signal from 2LO as applied to the grids is in

the region of 23 volts. No high frequency amplification is used. The aerial tuning inductance is loosely coupled to the closed circuit shown in Fig. 1, and the total capacity of the closed circuit is about 90$\mu\mu$F. Using a single valve detector a grid bias of 25 volts and consequent large value of anode voltage was necessary. With the arrangement shown in Fig. 1 the grid bias is reduced to 12 volts and the high tension voltage approximately halved with no apparent loss of signal strength.

A further advantage of the system is that, as far as the high frequency side is concerned, it is electrically symmetrical about earth. This fact prevents the tuned circuit itself acting to a certain extent in the manner of an elevated aerial, though of course it does not prevent it picking up signals in the manner of a loop aerial. The latter method of pick up can be prevented by winding the inductance astatically and arranging the aerial inductance, or primary of transformer in the case of high frequency or supersonic amplifiers, to couple with it.

In conclusion it may be stated that the author prefers this arrangment both for supersonic amplifiers and for reception of the local station even though it necessitates the use of an extra valve. The reason for using the arrangement for reception of the local station is reduction in voltage of the high tension battery needed.

One precaution is necessary in putting the arrangement into practice, more particularly when using anode current rectification. It is necessary that the characteristics of the two valves should be very nearly identical, otherwise the benefits will only be secured in part or not at all. The author has found that the Cosmos " S.P.18 green spot " valve is extremely suitable on account of its high voltage factor. The characteristics of these valves, however, vary considerably from valve to valve, especially about the lower bend. Incidentally, in plotting the characteristics for comparison, the anode resistance R_1 should be included in the anode circuit with a good milliammeter having a scale of 0-2 milliamperes. A suitable value for R_1 when using the Cosmos valve is 100,000 ohms. The value of high tension supply will of course depend solely upon the amount of grid bias required to prevent the flow of grid current. This value of bias is determined by the signal amplitude which may be anything from a small fraction of a volt to 20 or 30 volts.

The value of high tension required may be calculated from the formula

$$V = -\mu V_g$$

where V is the approximate value of high tension,
V_g is the grid bias,
μ is voltage factor of the valve.

The voltage factor of the Cosmos valve is about 15. If the signal amplitude is 4 volts, which is a reasonable value to expect either from a local station or supersonic amplifier, about —1 volt bias will be required with the Cosmos valve, since grid current commences at about 1.7 volts and only half the signal voltage is applied to each grid. Consequently, in these conditions, about 15 to 20 volts is all the H.T. required. In conditions such as these " Q " valves are extremely suitable with a grid bias of — 2 volts and about 100-150 volts high tension. When " Q " valves are used the anode resistance R_1 should not be less than about 300,000 ohms and should preferably have double that value. The " Q " valve has a voltage factor of about 50 and consequently a very high impedance. Valves such as the " D.E.5B," although very satisfactory, are unnecessarily expensive for the purpose, especially as only a very small emission is required. The " Qx " and " D.E.Q." are quite satisfactory for larger inputs than the " Q " will deal with but are again expensive. The " Q " valve is, of course, expensive both in first cost and in filament consumption, but on account of its high voltage factor is very valuable for dealing with moderate signals. For supersonic amplifiers the " Q " valve is the best known to the author since the input signal amplitude fed to the second detector rarely exceeds 2 or 3 volts.

Valve Current from A.C. Mains.

Description of a Method employed by the Author.

By J. K. Jennings, M.Sc. Tech.

IN this article a method of obtaining H.T. and L.T. supplies for a receiving set is described.

The object has been to devise a cheap form of apparatus which can be constructed easily in the experimenter's room.

The Apparatus.

The L.T. supply for the set is obtained from a step-down transformer, the primary of which is connected to the house A.C. mains.

The H.T. supply is obtained from additional windings on the same transformer. It is proposed to use a valve rectifier for the latter supply.

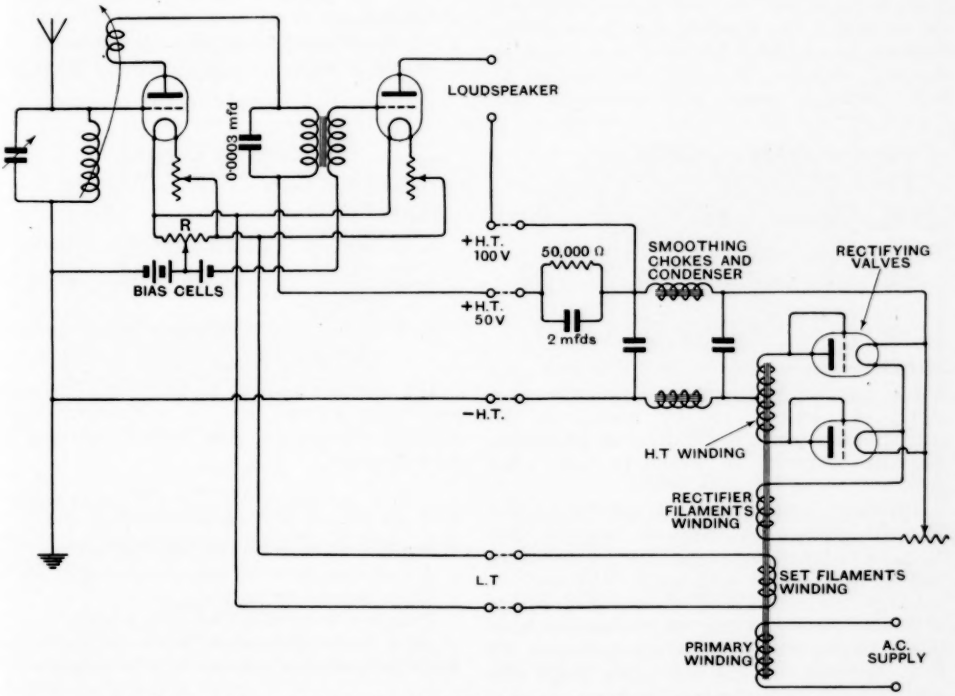


Fig. 1.—*The mains equipment circuit associated with a two-valve receiver.*

Apart from the convenience of the house mains as the source of energy for the set, in the method described running costs are very low and the initial outlay is not excessive. As every listener knows, battery expenses form the main item in the cost of running an ordinary set.

A complete diagram of connections for a two-valve set is given.

In Fig. 1 the two-valve set is shown separated from the extra apparatus, which is conveniently mounted on a separate panel.

Notes on the Circuit.

The set itself is connected as an ordinary detector and L.F. circuit, except that anode rectification has been adopted in preference to the more usual grid condenser and leak method. The former arrangement enables the A.C. hum to be more easily reduced. The value of the bias on the detector may be up to about 8 volts negative.

In the diagram it will be noticed that a potentiometer *R* has been connected across the filaments of the valves of the receiver, and that the grid circuits of both valves are connected to the potentiometer slider. The object of this arrangement is to reduce hum. Hum is produced in two ways: first by the cooling of the filament and the resulting decrease in emission between each peak in the A.C. supply; secondly, by changes in P.D. between mean grid potential and

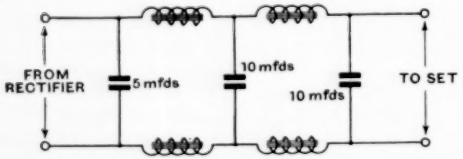


Fig. 2.

average filament potential. To cure the latter trouble the arrangement described above is adopted, for by means of the potentiometer we can produce an accessible filament midpoint to which to "tie" the grid.

The hum caused by the cooling of the filament cannot be removed entirely, but may be reduced by using low temperature valves, and valves with large filaments.

Large condensers and chokes (Fig. 2) are necessary for smoothing out the output from the rectifying valves before connecting to the H.T. terminals of the set. The larger the smoothing system the less the hum.

Half Ford ignition coils make excellent chokes. Choke coils to be effective must be worked on the steep part of their magnetisation curves. This means that the number of ampere turns should not be sufficient to saturate the iron section used.

Readers will notice that the method gives only one value of H.T. For this reason a 50,000 ohm resistance, shown in the diagram, has been inserted to obtain reduced H.T. for the detector valve. The resistance must, of course, be shunted with a 2μF condenser.

It will be seen that the most important part of the work is the construction of the transformer.

The complete design and calculation of a transformer is given below to meet the stated conditions, so that readers may substitute other figures to suit their particular cases.

The Transformer.

The transformer must have four separate windings for the following purposes:—

1. The primary, for connection to A.C. mains.
2. For filament supply to the set.
3. For filament supply to the rectifier.
4. For H.T. supply to the rectifier.

Transformer Design.

Input—220 volts 50 cycles.

Output—

1. To set L.T., $7\frac{1}{2}$ volts 2 amps. = 15 watts.
2. To rectifier L.T., $7\frac{1}{2}$ volts 2 amps. = 15 watts.
3. To H.T. supply, 220 volts across "outers."

Let average current to be passed through rectifying valves be 100 milliamps, then average current per side of H.T. winding is 50 milliamps.

$$\therefore \text{H.T. output} = \frac{50 \times \pi}{2\sqrt{2}} \times \frac{220}{1{,}000} = 12 \text{ watts.}$$

Approximate total output = 50 watts.
Assume transformer efficiency = 80 per cent.
Then input = 65 watts.
Primary wattful current = 0.3 amp.
As a first approximation we can take the full load primary current at 0.5 amp.

Estimation of Size of Transformer from Coil Cooling.

A current density of 140 amps per sq. cm. (900 amps per sq. in.) will be suitable provided the depth of winding is small.

This gives a cross section of wire of

$$\frac{.5}{140} = .00361 \text{ sq. cm.,}$$

and the nearest wire is No. 22 S.W.G. We shall use D.C.C. wire and allow 5 turns per volt.

$\therefore$ No. of turns on primary $=220\times5=1{,}100$.

For D.C.C. wire add .03 cm. to the bare diameter; then overall diameter .101 cm.

Assume depth of winding $=1.5$ cms.

Then

$$1{,}100=\frac{1.5}{.101}\times\frac{L}{.101}$$

where L = length of coil.

$$\therefore \quad L=7.5 \text{ cms.}$$

Allow a length of 8 cms.

Then the transformer up to the present is as shown in Figs. 3 & 3a, if we assume we use a standard lamination one inch wide (2.54 cms.).

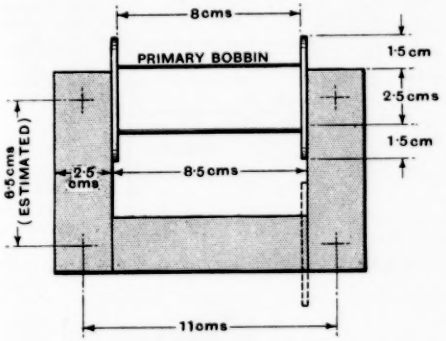


Fig. 3.

From the estimated sizes shown we find that the approximate length of iron path is 37 cms.

Iron Section.

Assume a 4 per cent. volt drop due to resistance of the primary, then induced volts $=220-8.8=211.2$ volts.

$$211=4.44\times N\times Qm\times f\times 10^{-8}.$$

where N = number of turns

Qm = maximum value of flux.

f = frequency.

$$\therefore \quad N\times Qm=.95\times 10^{-8}.$$

At $N=1{,}100$. $\quad Qm=.865\times 10^{-5}$ lines.

Allow a Bm of 10,000 lines per sq. cm.

At this value of B the amp turns per cm. length $=8$ and magnetising current

$$=\frac{8\times37}{1{,}100}=.296 \text{ amps.}$$

This is very reasonable.

Then section of iron required

$$=\frac{.865\times10^{5}}{10{,}000}=8.65 \text{ sq. cms.}$$

The depth of iron is then

$$\frac{8.65}{2.54}=3.4 \text{ cms.}$$

Allowing 10 per cent. for paper or varnish, outside size of iron

$$=\frac{3.4}{.9}=3.8 \text{ cms.}$$

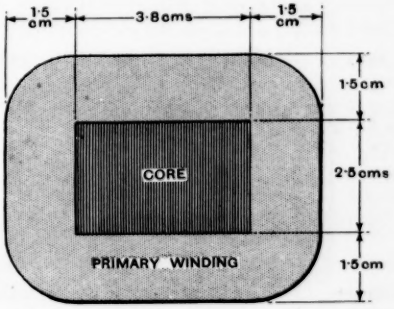


Fig. 3a.

Check Iron Loss.

At 50 cycles and 10,000 B_{max}. loss per cc. $=.033$ watt. Total volume of iron in core $=37\times2.54\times3.4=320$ cubic cms.

Iron loss $=320\times.033=10.5$ watts.

In view of the fact that the total losses in the transformer must not exceed 15 watts this figure for iron loss is on the high side.

We are now in a position to estimate the I^2R loss in the primary and to see what cooling surface is available to dissipate this loss.

Length of wire $=1{,}100\times$ mean length of turn.

Mean length of turn

$$=(3.8+1.5)\times2+(2.54+1.5)\times2$$

$$=18.7 \text{ cms.}$$

Length of wire $=1{,}100\times 18.7=20{,}600$ cms.

$\therefore$ Resistance of primary $=8.78$ ohms.

Approx. $I^2R=(.5)^2\times 8.78$

$=2.2$ watts.

Cooling area of primary coil

$=8\times 5.5\times 2+8\times 6.8\times 2$

$=197$ sq. cms.

which gives 90 sq. cms. per watt, which is ample.

The iron and primary coil have now been dealt with.

The L.T. Coils.

The L.T. coils are similar in all respects. The output required is $7\frac{1}{2}$ volts 2 amps. In these coils we can afford to raise the current density to 200 amps per sq. cm. because the winding will contain less insulation.

$$\text{Area of conductor} = \frac{2}{200} = .01 \text{ sq. cm.}$$

This area is very nearly met by No. 18 S.W.G. wire.

The diameter of No. 18 wire $=.122$ cm. bare with D.C.C. diameter $=.152$ cm.

$$\text{Number of turns necessary} = \frac{8}{211}\times 1{,}100$$

$$= 42 \text{ turns}$$

(allowing for .5 volt drop in the L.T. winding and leakage).

Assume depth of winding 1 cm.;

$$\text{then} \quad 42 = \frac{1}{.152}\times\frac{L}{.152}$$

where L = length of coil.

$L = .97$ cm., say 1 cm.

A length of 1 cm. for each L.T. winding seems suitable.

The H.T. Winding.

It will be convenient to put the two L.T. windings and the H.T. winding on the same limb of the core. For this reason we shall, if possible, limit the length of H.T. winding to $8-(1+1+1.5)=4.5$ cms.

(The allowance of 1.5 cms. is for insulation between the windings.)

It will be remembered that this winding will have a middle tapping.

Volts across "outers" is to be 220.

$$\therefore \quad \text{Turns} = \frac{1{,}100\times 220}{211} = 1{,}140.$$

Add 10 per cent. for various drops.

This gives us 1,250 turns on the H.T. winding. R.M.S. current $=55$ milliamps.

Allow density of 150 amps per sq. cm.

$$\therefore \quad \text{Section of wire} = \frac{.055}{150} = .000368 \text{ sq. cm.}$$

No. 32 S.W.G. wire has a section .00059 sq. cm., and we shall, for mechanical reasons, use this.

Diameter of No. 32 wire $=.0274$ cm.; add .016 cm. for D.S.C., which gives .043 cm. as total diameter of wire.

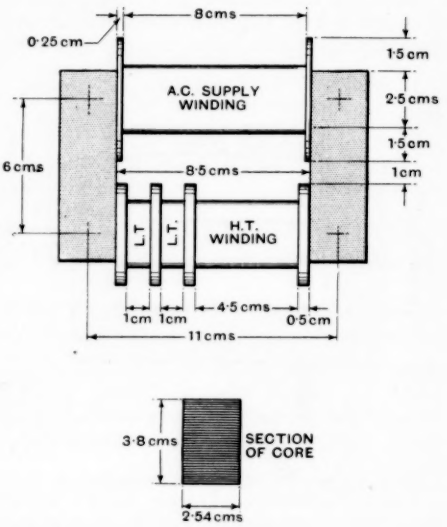


Fig. 4.

To find depth of winding D:—

$$\text{Then } 1{,}250 = \frac{4.5}{.043}\times\frac{D}{.043}. \quad D = .514 \text{ cm.}$$

This depth is rather less than it need be, and D.C.C. wire could probably be used. Total diameter D.C.C. No. 32 wire $=.0574$ cm.

$$\text{Then} \quad D = \frac{1{,}250\times .0574\times .0574}{4.5}$$

$$D = .92 \text{ cms.}$$

which is quite suitable. We shall use D.C.C. wire.

Drop and Watts Lost in H.T. Winding.

Mean length of turn
$= (3.8 + .92) \times 2 + (2.54 + .92) \times 2$
$= 16.2$ cms.

Length of wire $= 1{,}250 \times 16.2 = 20{,}200$ cms.

Resistance = 58.3 ohms.

IR drop = 3.2 volts.

I^2R loss = .177 watt.

The cooling will be ample.

In the estimate made we allowed for a depth of winding of 1.5 cms. for the H.T. winding. Then we may now reduce the lengths of the cross limbs of the core to 6 cms. instead of 6.5.

The finished transformer core bobbin is is shown in Fig. 4.

A summary of the main sizes of transformer material is given below in tabular form, with lengths of wire and weights given in yards and ounces respectively :—

	Primary.	Set L.T.	Rectifier L.T.	H.T.
L'gth of bobbin	8 cm.	1 cm.	1 cm.	4.5 cm.
No. of turns	1,100	42	42	1,250
Size of wire	22 S.W.G.	18 S.W.G.	18 S.W.G.	32 S.W.G.
Length of wire	225 yds.	8 yds	8 yds.	220 yds.
Weight of wire	1 lb. 12 oz.	4 oz.	4 oz.	5 oz.

In Fig. 4 the bobbins are shown in position on the core legs, actually they must be wound before assembling in this way.

The core will consist of soft iron laminations 2.54 cms. wide (1 inch standard iron) and should be built up to 3.8 cms. when compressed. The weight of iron required will be about six lbs.

Half of the laminations should be cut into lengths of 8.5 cms., and the remaining half into equal numbers of lengths of 3.5 cms. and 13.5 cms.

Three sides should be built up as indicated in Fig. 5.

The bobbins may be made out of presspahn or fullerboard, 15 mils. thick, the layers and ends being well shellacked together and dried.

Readers will be well advised to make a wood former .2 cm. larger than the core size on which to shape the bobbin and wind the wire. The completed coil may then be slipped over the legs of the core easily.

The body of the bobbins may be made out of two thicknesses of the insulation, and the ends out of four or five thicknesses. Care should be taken to bring out the middle tap on the H.T. winding between two pieces of insulation.

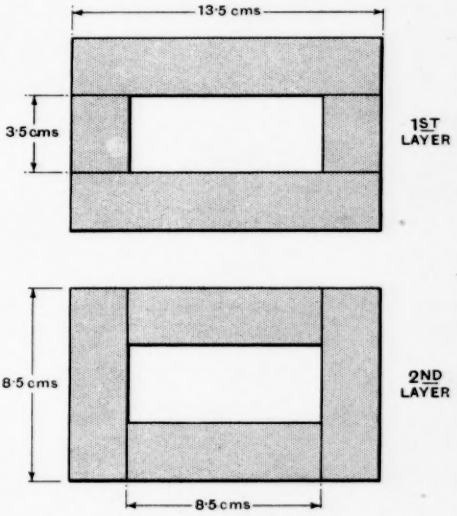


Fig. 5.

When the coils have been put on and the core finished off, two clamps should be fitted to the transformer core as shown in Fig. 6.

Readers should be careful to see that the bobbins are held tight on the core. This may be effected by inserting insulation at the ends of the bobbins after the transformer has been assembled.

The Rectifier and Lay-out of Apparatus.

The rectifier will consist of two power type valves, which may be conveniently mounted on a separate panel. In Fig. 1 the extra apparatus has been arranged apart from the original two-valve set, and the dotted lines between terminals represent external wires connecting the two units.

The potentiometer *R*, which should have a resistance of about 300 ohms, is shown in the original set. This arrangement is very convenient, and it should not be difficult to find room for this small component on the original panel.

their respective plates in order to increase the available D.C. output. The insulation of the rectifier filaments winding on the transformer is important because this winding, and also the rheostat, are at the H.T. potential. The set will operate as with

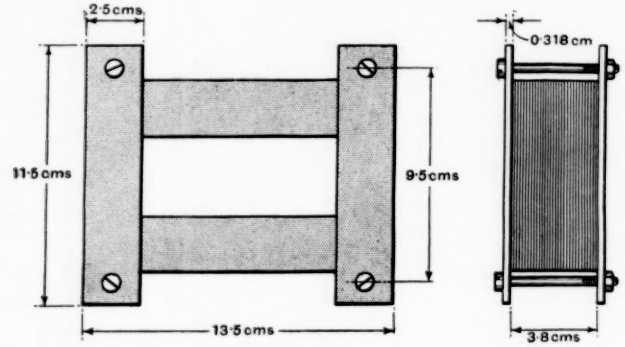


Fig. 6.

There are no special points about the rectifier and the complete diagram of connections (see Fig. 1) shows the wiring clearly. It will be noticed that the grids of the rectifying valves are connected to batteries as soon as the potentiometer *R* and the negative bias values have been adjusted.

It is hoped that the method described will prove of interest to other experimenters who are tackling the battery problem.

The Radiation Resistance and Energy Capacity of Half-wave Aerials.

By E. Green.

IN otherwise well-informed wireless circles there seems to be some ignorance of the properties of the antenna in use on short waves. Thus we find it stated in a recent manual that one of the difficulties on short waves is to get an appreciable power in the aerial owing to its small capacity. The real truth of the matter is exactly the reverse; it is on long waves that it is difficult to deal with large powers in the aerial, while on short waves it is comparatively easy. The normal type of aerial used in short wave work is a vertical wire, *XY*, about half a wavelength in length, the current and voltage distribution being as shown in Fig. 1. It may be excited by a quarter-wave coil Y_2 or by a capacity coupling. It will be shown later in the article that for a half-wave aerial, at any wavelength, the following statements are true :—

Radiation resistance of half-wave aerial referred to current at centre of aerial = 80 ohms

Voltage above earth at ends of aerial for 1 ampere at centre of aerial ... ... = 500 approx.

$\therefore$ Current at centre of aerial for 500kW radiated ... = $\sqrt{\frac{500{,}000}{80}}$

= 79 amperes

$\therefore$ Voltage at ends of half-wave aerial for 500kW radiated ... ... = 79×500

39,500 volts R.M.S.

This latter is a voltage for which it would be quite easy to provide insulation, so that the practical limit to the radiation of energy

on short waves at present is not the aerial but the transmitter.

We may contrast these figures with those for the aerial of the British Post Office Station at Rugby as given by Mr. Shaughnessy in his paper before the I.E.E.* From this we take the following figures :—

Effective height of aerial = 185 metres
Wavelength ... = 15,500 metres
Aerial current ... = 600 amperes
Aerial kilowatts ... = 306
Voltage on aerial ... = 180,000 volts R.M.S.

At this wavelength the radiation resistance is :—

$$1{,}580\left(\frac{185}{15{,}500}\right)^2 = \underline{.225 \text{ ohms.}}$$

Kilowatts radiated for 600 amperes in aerial $= 10^{-3} \times 600^2 \times .225 = 81$kW.

If we take 20 per cent. as a maximum value for the earth losses when using a half-wave aerial we get the following comparative figures :—

	Rugby aerial.	Half-wave aerial.
Aerial kilowatts ...	306	100
Kilowatts radiated	81	80
Aerial efficiency ...	26.5%	80%
Aerial voltage	...180,000 R.M.S.	15,000 R.M.S.

This table proves nothing as regards the relative advantages of long and short-wave

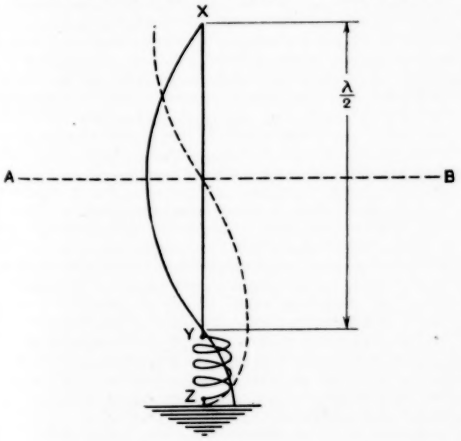


FIG. 1.

transmission, but it certainly shows in a striking manner that the difficulties on short wavelengths do not lie in the aerial system.

* 14th April, 1926. For Abstract see *E.W.*, May 1926, p. 271.

The calculation of the constants of a half-wave aerial is as follows :—

1. Radiation Resistance.

The ordinary formula for the radiation resistance of an earthed aerial is :—

$$R_a = 1{,}580\ (h/\lambda)^2 \text{ ohms}$$

where R_a = radiation resistance
h = effective height of aerial
λ = wavelength

We can cut the half-wave aerial through the centre by a conducting plane $A\ B$ in Fig. 1 and regard it as made up of two earthed quarter-wave aerials.

Effective height h for $\frac{1}{4}\lambda$ aerial =

$$\tfrac{1}{4}\lambda \cdot \frac{\text{Arithmetic mean value of sine curve}}{\text{Maximum value of sine curve}}$$

$$= \tfrac{1}{4}\lambda \frac{2}{\pi} = .159\lambda$$

$$\therefore \text{ Radiation resistance of } \tfrac{1}{4}\lambda \text{ aerial} = 1{,}580\left\{\frac{.159\lambda}{\lambda}\right\}^2 = 40 \text{ ohms}$$

$\therefore$ Radiation resistance of $\frac{1}{4}\lambda$ aerial referred to current at the centre = 80 ohms

2. Ratio of Maximum Voltage to Maximum Current.

To determine this we can use the fact that when the voltage amplitude is a maximum the current is zero, and *vice versa*, whilst the energy in the two cases is the same.

Let I = Maximum current at base of $\frac{1}{4}\lambda$ aerial.
V = Maximum voltage at free end.
L = Inductance in henries of $\frac{1}{4}\lambda$ wire for uniform current.
C = Capacity in farads of $\frac{1}{4}\lambda$ wire for uniform voltage.
l = Length of $\frac{1}{4}\lambda$ wire.
r = Radius of wire.

If the current were uniform the electrokinetic energy would be $\frac{1}{2}LI^2$. But since the current has a sinusoidal distribution the electrokinetic energy is $\frac{1}{2}L \times$ average value of $(I \sin\theta)^2$ between 0 and $\pi/2$.

The average value of $(\sin^2\theta)$ for these limits is $\frac{1}{2}$.

$\therefore$ Electrokinetic energy $= \frac{1}{4}LI^2$.

A similar argument shows that the electrostatic energy $= \frac{1}{4}CV^2$.

Equating these two forms of energy we get :—

$$\tfrac{1}{4}LI^2 = \tfrac{1}{4}CV^2$$

or

$$V/I = \sqrt{L/C}$$

To calculate the value of $\sqrt{L/C}$ we have the formulæ :—

$$L = 2l\left(\log_e \frac{2l}{r} - 1\right) 10^{-9} \text{ henries}$$

$$C = \frac{l}{2\left(\log_e \frac{2l}{r} - 1\right)} \frac{1}{9 \times 10^{11}} \text{ farads}$$

whence

$$\sqrt{L/C} = 60\left(\log_e \frac{2l}{r} - 1\right)$$

The value of this expression does not vary rapidly with practical ratios of l/r.

Taking

l = 10 metres, r = 1*mm*, $2l/r$ = 20,000.

$$V/I = \sqrt{L/C} = 60(4.301 \times 2.303 - 1) = \underline{534}$$

If a ratio of l/r = 1,000 had been used we should have found $\sqrt{L/C}$ = 400 and we shall take 500 as a fair average value. The ratio of V/I will be approximately the same for a half-wave aerial as for a quarter-wave earthed aerial. In this calculation we have used the maximum values of V and I, but the ratio is unchanged if both are R.M.S. values.

Book Review.

WIRELESS DIRECTION-FINDING AND DIRECTIONAL RECEPTION. By R. Keen, B.Eng., A.M.I.E.E. Second and Enlarged Edition, 490 pp., with 329 illustrations. London: Iliffe and Sons Ltd., 1927. Price 21s. net.

The application of directional wireless as an aid to both aerial and marine navigation is steadily gaining in popularity, and the mariner and pilot are learning that a wireless direction-finder used under proper conditions is at least as reliable as other and older navigational instruments. In addition to this application the directional receiver is now in common use to obtain increased selectivity in wireless communication, and also as a powerful instrument in scientific research on the phenomena of the propagation of wireless waves over the earth's surface. Workers in all these branches are now adequately catered for in the volume under review. It is pleasing to find that in the second edition of his book, Mr. Keen has met practically all the criticisms levelled against the first edition. The book has been very thoroughly revised and brought up to date. A considerable enlargement has resulted from the extension of its scope to include an account of directional receiving systems of the beam, Beverage antenna and closed loop types, which are now of such vital importance in dealing with the continually extending commercial services.

In the early chapters the fundamental theory of aerial systems and the closed loop direction-finder is clearly dealt with in language which makes only the simplest demands upon the mathematical ability of the reader. The practical arrangements of the most important commercial types of rotating frame-coil direction-finder in use at the present time are described with the aid of a large number of photographs and diagrams. Later chapters deal with the Bellini-Tosi system of direction-finder and carefully prepared working details are given of the installation of this system at both ship and shore stations. Opportunity is found here also of introducing a description of the multi-way directional receiving arrangements in which eight communication channels are operated simultaneously from one pair of Bellini-Tosi loops. Direction-finding in the air, and the special problems connected therewith are treated in a separate chapter, while attention is drawn elsewhere to the merits of the directional beacon transmitter.

The operator of a wireless direction-finder soon discovers that he must become familiar with the elements of field and nautical astronomy and the use of the various types of maps and charts, but he will find his needs fully catered for in the two chapters dealing with these subjects. The chapter entitled "Night Effect and Other Freak Phenomena" has been revised in a way which shows that the author has kept thoroughly abreast of modern scientific research; and the subject is presented in a manner which gives a true perspective of the problem to the wireless operator and navigator, so enabling them to avoid possible errors which might arise in the use of the direction-finder over long ranges at night. A bibliography arranged in an excellent manner and comprising 374 references in chronological order from 1893 to 1927 forms a very valuable portion of the book, which concludes with a useful index.

Altogether the writer has had great difficulty in finding anything to criticise in a book which has been conscientiously written and produced in a manner which leaves nothing to be desired. The work can be confidently recommended as a very reliable handbook to all those interested in the science and practice of directional reception, whether as navigators, operators, engineers or experimenters.

R.L.S.-R.

Rotating-Beacon Radio Transmitters.

Papers read before the Wireless Section, Institution of Electrical Engineers, on Wednesday, 4th January, 1928.

At the meeting of the I.E.E. Wireless Section held on 4th January, three papers were read on the subject of Rotating-Beacon Radio Transmitters.

Abstracts of the three papers and of the general discussion which followed their reading are given below.

* * * *

(1) Rotating Loop Radio Transmitters and their application to Direction-finding and Navigation —by T. H. Gill and N. F. G. Hecht, M.I.E.E.

ABSTRACT.

This paper deals particularly with a method of directional transmission which has been developed by the Air Ministry at the Instrument Design Establishment, Biggin Hill, and later at the Royal Aircraft Establishment, South Farnborough. The principal object of the method is to eliminate direction-finding equipment and to reduce operational difficulties in aircraft.

The advantages of the system are: (*a*) No special receiving apparatus is required and any ordinary receiving set can be employed; (*b*) Observations are simple to make and operators do not require even to be very skilled in reading Morse; (*c*) The characteristic to be observed is usually well defined; (*d*) No quadrantal error arises and no corrections of the bearings are required; (*e*) Any number of craft can use the system simultaneously.

Methods Investigated.

In the paper brief accounts are given of some of the methods of directional transmission investigated. These first included Bellini-Tosi transmission and the "variable wavelength method," described by J. Erskine-Murray and J. Robinson,* after which the investigations were confined entirely to the single rotating-loop transmitter dealt with by the authors.

R.A.F. Rotating Loop Transmitter.

(*a*) *General Principles.*—When a loop is used as a transmitter maximum energy is radiated in the plane of the loop and minimum at right angles, giving the usual "figure of eight" polar diagram of Fig. 1. If the loop be rotated in azimuth an observer at any point on the circumference will receive a signal with two maxima and two minima in every revolution of the loop. If the loop rotates uniformly at a speed of say, one revolution per minute and a distinctive signal is sent out when the plane of the loop is North-South, the observer can obtain the time interval between the N.-S. indication and the moment of maximum or minimum signal, from which his bearing with respect to the loop is easily deduced. As usual, the minimum indication is preferable, being much more sharply defined.

It is shown in the paper that the magnetic field radiated from a coil is equal to the field from one side of the coil multiplied by the phase angle θ corresponding to the distance l between the sides

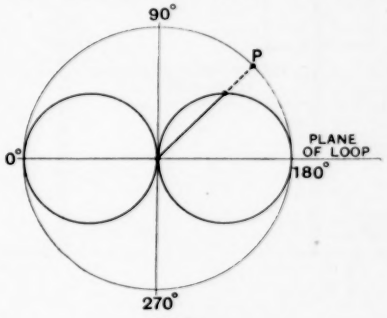


Fig. 1.

of the coil in terms of the wavelength. While this is small compared with the radiation from an open aerial with the same current, it is important to note that the high-frequency resistance of a loop can be made very small, and it is therefore possible to produce much greater oscillating current in a

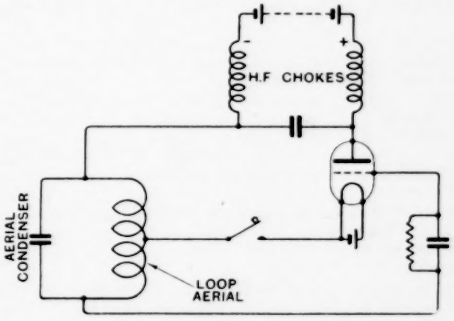


Fig. 3.

loop than in an aerial for the same primary input power. The comparison between loop and aerial is therefore much more favourable than might appear at first sight.

(*b*) *Development.*—An account is given of the work done in the development of the rotating loop transmitter. The first coil used was 10 ft. square

* *J.I.E.E.*, 1922, Vol. 60, p. 352.

with four turns spaced 6 in. apart. The bottom of the coil was 4 ft. 6 in. above ground level. The coil was tuned to 1,100 m. by a condenser, and the whole circuit energised by a standard R.A.F. transmitter to give I.C.W. signals. Very good minima were observed when the loop was rotated by hand, but on uniform rotation it was noticed that these were not of equal intensity and were not 180 degrees apart, due presumably to the well-known " antenna effect." A small change of wavelength was also discernible, especially when C.W. was used.

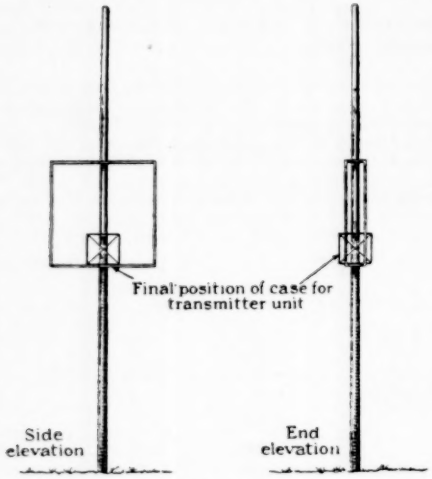


Fig. 6.

After various experiments on the height of the loop and the disposition of the apparatus, a satisfactory arrangement was produced as shown in Figs. 6 and 7,* utilising the circuit shown in Fig. 3.

The H.T. generator and the batteries for heating the valve filament were placed in the hut (on ground) and connected to the transmitter by slip rings and brushes. The leads were metal braided cable with the braiding earthed. The transmitted wavelength remained constant during the rotation of the loop, and the minima were practically equal in intensity, and very sharply defined. The keying of the circuit was automatically carried out by the rotation of the loop.

The development then proceeded mainly along the lines: (1) Removal of mechanical difficulties in housing and rotating the loop aerial; (2) Increase of range; (3) Production of perfect minima 180 degrees apart; (4) Use of I.C.W. to enable re-

* The authors' original figure numbers are adhered to throughout these Abstracts.

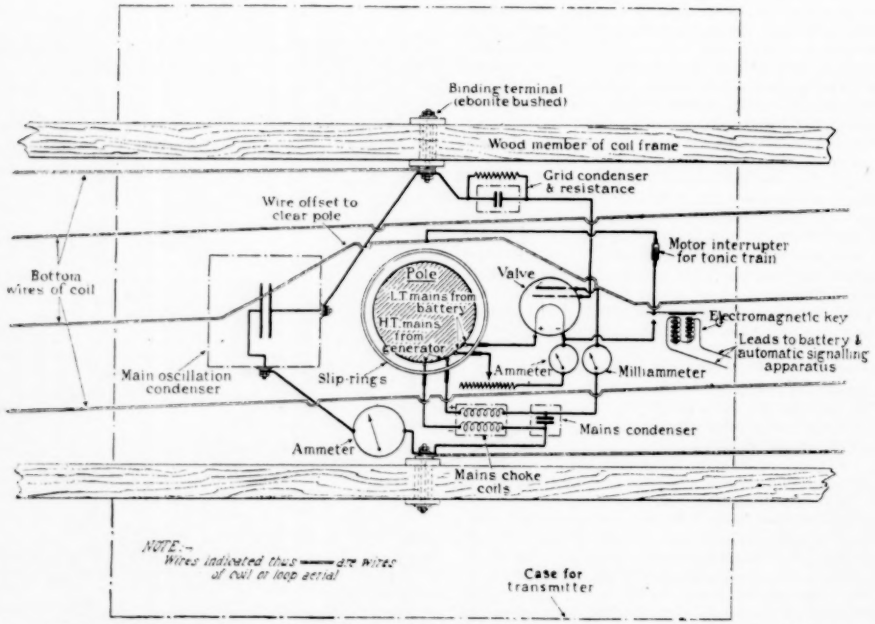


Fig. 7. *Directional transmission from a loop aerial. General arrangement of transmitter (schematic). Part plan of lower portion of coil and transmitter.*

ception to be effected on simple spark receiving sets such as are used on ships.

The housing and protection of a loop of the size hitherto used was very difficult. A smaller loop was therefore decided upon, with a reduction of wavelength (to 525 metres) to compensate for the loss of range consequent on reduction of coil. The new coil was of six turns on a frame 5 ft. square, tuned by a condenser of 0.00088μF. The condenser consisted of nineteen aluminium plates, each 36 in. by 18 in. and spaced $2\frac{1}{2}$ in. apart with spacing pieces of American white wood. More recently the wavelength of the Farnborough Beacon has been changed from 525 to 707 metres, chiefly on account of the interference from other stations. The size of the frame remained unaltered, but additional strands were added to the turns of the loop, which now consists of 1,458/40 S.W.G. black enamelled wire. The aerial condenser is made up of thirteen plates each 4 ft. 9 in. by 2 ft. 6 in., spaced 2 11/16 in. apart, giving a capacity of approximately 0.00166 μF. The loop current is 72 amperes and the H.T. input is about 2,500 watts (250 milliamperes at 10,000 volts). The H.T. supply is from an A.C. generator, stepped up and rectified by two valves giving full wave rectification. Batteries for heating the oscillating and rectifying valve filaments were dispensed with and step down transformers used on the A.C. supply.

Although the minima obtained were then 180 degrees apart, it was found that they were of unequal intensity. This was found to be due to the condenser plates—now of dimensions comparable to those of the coil—having their planes parallel to that of the loop. Refixing them with their planes at right angles to that of the loop gave minima more nearly equal in intensity. They are still slightly different, but bearings can be taken from either with the same degree of accuracy.

Some of the asymmetrical effects are possibly due to local conditions, as differences are noticeable between the performance of the 525 metre beacon at Farnborough and that at Gosport, although the two are identical except for the sites which differ considerably.

(*c*) *Timing Signals.*—In the first experiments the indication of the North-South position was given when the frame was oriented North-South and giving maximum radiation in this plane. It is now arranged that the North-South indication shall be transmitted when the radiation in this direction is a minimum. The method of signalling is shown in Fig. 9. The letter " V " is sent as a warning that the North point is approaching, followed by two timing dots which, with the commencement of the continuous signal, can be counted as three. The observer counts " one," " two," " three " in time with the signals and releases the stop watch or chronograph on " three." The letter " B " is used as a warning for the East point. The East signal is necessary to overcome the difficulty of receiving the North indication when the craft is North or South of the beacon, as on that bearing signal strength is a minimum, and it is then more satisfactory to obtain a timing signal corresponding to a minimum radiation in an East-West direction. The beacon is calibrated on time North.

(*d*) *Best Speed.*—It has been found that a speed of one r.p.m. is probably the best for this type of beacon in addition to which it is the same as that of the second's pointer of watches. Actually a speed of one revolution for 72 seconds gave most consistent results, but there was so little difference between that and 60 seconds that it was decided to adopt the latter, rather than introduce special time pieces.

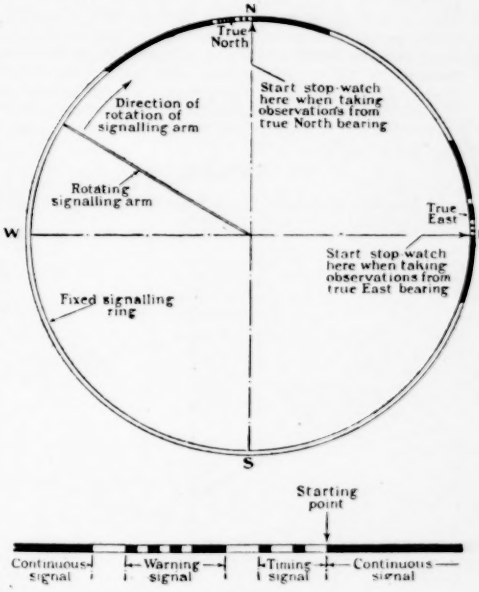


Fig. 9.

(*e*) *Speed Control.*—It is essential that the loop should rotate at a constant speed, uniform throughout each revolution. Up to the present a suitable method has not been put into use for performing this without manual assistance. The problem of speed control is being investigated and two methods are about to be tried.

(*f*) *Use of Beacon in Navigation.*—Apart from its use for position finding by two or more beacons, the rotating loop appears to have a particular use in point-to-point work, which in many cases can be conducted on a single beacon. Examples are shown in Fig. 10. If an aeroplane be required to fly from *A* (beacon station) to *B*, Fig. 10 (*a*), if the bearing of *B* be, say, 300 degrees and the beacon be rotating at six degrees per second, the signal for stating the chronograph will be sent out when the N.-S. radiation is a minimum. If the navigator maintains a correct course he will hear the minimum signal at 50 seconds on the chronograph or on 300 degrees, if the dial is calibrated in degrees, with reciprocal minimum at 20 seconds or 120 degrees. Listening to the beacon and observing time of minimum he can fly from point to point

using the beacon as his sole aid to navigation. In the case of flying from *C* to *B*, Fig. 10(*b*), he can first steer North until he arrives at a point where the observation of the beacon will occur at the correct time, when he must alter his course and proceed in the manner indicated above. Flights of this nature have been carried out up to a distance of 160 miles, with entirely successful results. In Fig. 10(*c*), if terminal air posts are at *A* and *B* respectively and each has a beacon, the traffic lines could be arranged as indicated, navigation being performed as in the second example quoted.

(*g*) *Night Effect in Air.*—Although it would be premature to say that this method is free from night variations, up to the present no variations of direction have been noticed, although on many occasions the observer has particularly looked out for them.

Appendix.

A lengthy appendix gives various tables of results from ground tests and air tests.

Number of bearings taken = 95.

Accuracy	OK	±1	±2	±3	±4	±5
No. of bearings..	12	27	18	9	10	6

Accuracy	±6	±7	±8	±9	±10
No. of bearings..	5	4	2	1	1

From the trials it seems that errors in bearings are due to the following causes :—

(*a*) Faulty stop watch.
(*b*) Beacon erratic in time of rotation.
(*c*) Apparent errors due to faulty pin pointing.
(*d*) Errors due to wrong setting of beacon.
(*e*) Errors caused by wide minima due to weak signals or strong interference.
(*f*) Errors caused by lack of practice.
(*g*) Errors due to incorrect timing between second pilot and operator.

All of these faults have occurred during the test trials carried out, and some allowance for these errors should be made when judging the reports. It is probable that the bearings obtained were better than they appear in the various reports.

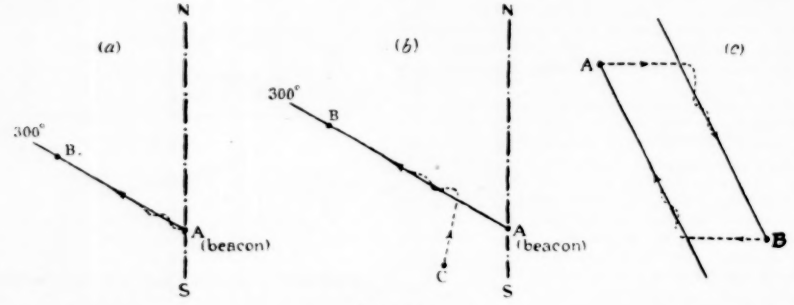


Fig. 10.

The following extracts taken from reports give typical examples of results obtained during recent extensive tests carried out in aircraft in May and June 1927.

Accuracy of Bearings.—A total of 558 bearings were taken, resulting as follows :—

Accuracy	OK	±1	±2	±3	±4	±5
No. of bearings..	65	104	97	87	64	40

Accuracy	±6	±7	±8	±9	±10	±11
No. of bearings..	26	30	21	6	6	5

Accuracy	±12	±13	±14	±15
No. of bearings..	1	3	2	1

It should be borne in mind, however, when considering the above table that it includes *all* bearings taken and thus includes errors due to inexperienced operators, minor faults in beacon itself, inaccurate timing due to wireless telegraph interference, etc. In view of this, the following block of bearings are given as taken by a fairly experienced operator when the beacon was known to be correct in itself and when wireless interference was at a minimum.

* * * *

Some Experiments on the Application of the Rotating-Beacon Transmitter to Marine Navigation. — by R. L. Smith-Rose, D.Sc., Ph.D., A.M.I.E.E., and S. R. Chapman, M.Sc., A.M.I.E.E.

ABSTRACT.

The rotating-beacon transmitter was exactly similar to that described by Messrs. Gill & Hecht in the previous paper. It was set up by the Air Ministry at Fort Monckton near Gosport in July, 1926, and loaned to the Radio Research Board for the purpose of conducting the experiments described in the present paper. The beacon was operated throughout on its normal wavelength of 525 metres.

The site being chosen more for convenience than for its wireless virtues, and detailed calibration of the beacon was carried out by taking bearings from fixed points in various directions. When the

path of transmission is partly or entirely overland, the observed bearings are subject to a small permenent error, evidently associated with a coastal deviation effect similar to that experienced in ordinary direction finding. When the bearings were made in the small open sea sector or in the open sea beyond the Isle of Wight, the permanent error was limited to one degree or two degrees.

Experiments carried out at Sea.

With the assistance of the Southern Railway Co. and of H.M. Signal School, experiments were carried out at sea on the routes shown in Fig. 2.

The experience gained on these and other sea trips suggested that bearings observed on the beacon have an accuracy somewhat superior to that obtained from an estimate of the ship's position, except when the ship was in calm weather and it was possible to make a fairly accurate visual fix. Further experiments on night error are described in the next section.

Tests Carried Out at Fixed Positions on Sea and Land.

A continuous series of observations was made on the beacon from various positions, each test lasting

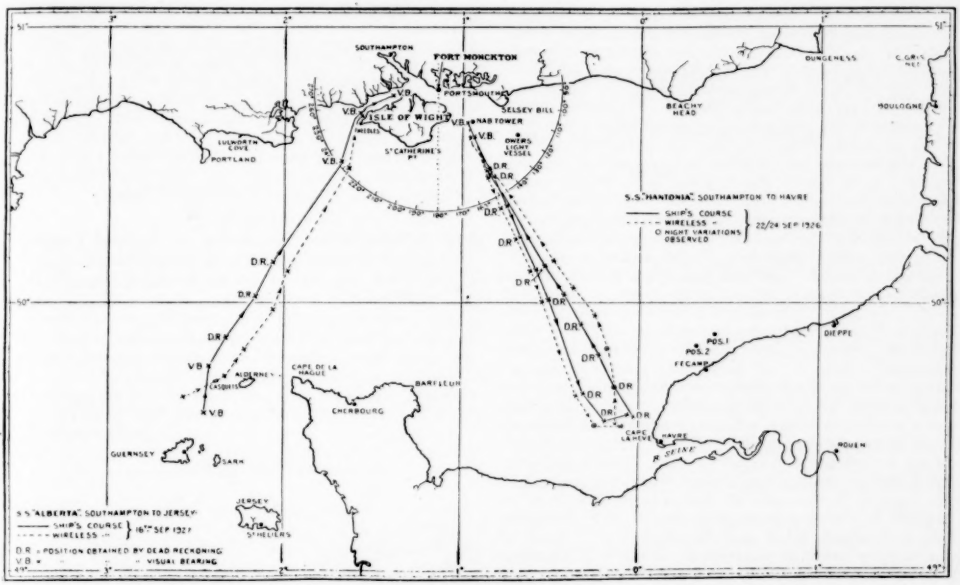


Fig. 2. *Chart showing portion of the English Channel utilised in the tests of the radio beacon with ships. Typical courses are shown for the trips between Southampton and Havre and Southampton and Guernsey, also the sites of the fixed-position tests are shown at Owers Light Vessel, Fécamp (1 and 2), Havre and Jersey (St. Heliers).*

(*a*) *Between Southampton and Havre.*—Path entirely oversea, and of almost constant bearing. Differences between wireless bearing and that obtained from ship's position by dead reckoning up to nine degrees, but majority agreed to within two degrees. Wireless bearing possibly more accurate, and larger differences possibly due to incorrect estimation of ship's position. Night effect observed in the form of blurred minima and tendency of successive bearings to wander erratically.

(*b*) *Between Portsmouth, Fécamp and Owers Light Vessel.*—Also in open sea path; trips in daylight but poor visibility. Maximum difference between observed and estimated bearings up to five degrees.

(*c*) *Between Southampton and Channel Islands.*—Isle of Wight intervenes in wireless path. Outward journey by day and return by night. Differences ranging up to 12 degrees, and night errors experienced at distances exceeding 50 miles.

for 12 hours or more. The positions were selected so as to provide a variety of ranges and also to show the difference between transmission over sea and land.

The results were analysed and the authors drew the following conclusions: (i) The maximum error by day at distances up to 56 miles overland or 92 miles oversea is 6 degrees. Up to 23 miles over 85 per cent. of all observed bearings are correct to 2 degrees. (ii) At night the above accuracies hold for distances of 14 miles overland and 23 miles oversea.

(iii) At 92 miles oversea night errors up to 18 degrees may be encountered, but over 84 per cent. of the observed bearings are correct within 5 degrees.

(iv) At 55 miles overland the errors are much more serious at night and may range up to 32 degrees.

(v) The mean bearing of any position is practically the same for day and night. The effects of (iii) and (iv) may be largely compensated for by taking the mean of a number of successive bearings.

(vi) As far as concerns the distances at which night errors are encountered there is practically no difference between C.W. and I.C.W. transmissions.

Comparison of Bearing Observations by Beacon and by Direction-finding.

(*a*) *Day Tests at Various Positions.*—Tests were made at different positions on land by a simple receiver for reception of signals from the rotating beacon and a single coil direction finder taking D.F. bearings on the beacon, while this was of fixed orientation, maximum for the receiver. The aerial and D.F. coil were at sufficient distance to avoid mutual interference, while the former was additionally disconnected during observations by the latter.

The results were summarised in tabular form. The error of the mean bearing observed on the D.F. set is generally different from that observed on the rotating beacon, but the range of errors on the two systems is of about the same order. These errors are considered to be due to deviations of the waves at the boundaries between sea and land, and it is suggested that the beacon provides a useful means of investigating this phenomenon since it can be used as a "null" method for transmission in the desired direction.

(*b*) *Day and Night Errors Compared.*—Tests were carried out to study the variations observed with the two systems over period of from one hour upwards. One set of tests was made at Slough using a single coil direction finder and another receiver on a vertical aerial. Another set was done at Jersey Quay on board a Southern Railway Co.'s ship, using the ship's D.F. set and the ordinary aerial respectively. Results were shown in tabulated form. Variations range from 20 degrees to 57 degrees in the case of the beacon and from 69 degrees to 130 degrees in the case of D.F. bearings, but even under these conditions over 86 degrees of the beacon bearings and over 62 of the D.F. bearings are within 10 per cent. It is therefore concluded that both systems of obtaining wireless bearings are subject to night errors of the same serious order, but the effect may be mitigated by taking the mean of a number of successive bearings.

(*c*) *Comparison Tests at Sea.*—Some of the test-runs between Southampton and Jersey were done on ships fitted with D.F. which enabled similar comparisons to be made under sea-going conditions. Maximum differences between estimated and observed bearings on the beacon are shown up to 19 degrees in daylight, and between estimated and D.F. bearings up to 14 degrees in daylight. These errors are large for daylight working and are considered as being due probably to inaccurate estimation of the ship's position, as the weather was very bad.

In conclusion the authors make a comparison between the bearings observed on the rotating beacon and those obtainable with a direction-finder used in the ordinary manner. When used in fixed positions on land the direction-finder gives a somewhat superior accuracy, as it is not easy to obtain bearings on the rotating beacon to an accuracy of less than 2 degrees, whereas a good land direction-finding station should give bearings reliable to 1 degree. As is well known, however, the land direction-finding station is subject to errors due to local conditions which necessitate its frequent calibration, but the observed bearings from the rotating beacon have been shown to be largely immune from conditions local to the receiver. When the wireless bearings are taken on board a ship at sea, however, the case is somewhat different. The direction-finding bearing is taken relative to the direction of the ship's head, and its accuracy depends upon the steadiness of the ship and also upon the accuracy with which the ship's head is given by the compass reading at any desired instant. The bearing obtained by the rotating beacon is entirely free from this limitation and its accuracy is practically the same whether the ship is at sea, in motion or at anchor, or in dock. Furthermore, no correction or compensation corresponding to the quadrantal error associated with the ship direction-finder is necessary. The limitation of range of accurate bearings due to night effect has been shown, both theoretically and experimentally, to affect both systems to the same degree.

* * * *

(3) A Theoretical Discussion of Various Possible Aerial Arrangements for Rotating-Beacon Transmitters—by R. L. Smith-Rose, D.Sc., Ph.D., A.M.I.E.E.

This paper discusses three aerial arrangements for a rotating-beacon transmitter from the theoretical point of view. The three systems are the single

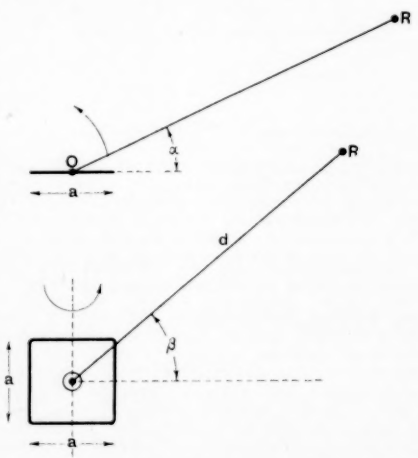


Fig. 1. *Single-frame coil transmitter at* O. *Receiver at R, distance d, orientation* α, *and elevation* β.

coil, the double spaced coil, and the Adcock aerial arrangement.

(1) Single Rotating Coil Transmitter.

(*a*) *General Equation for Radiation.*—The conditions are shown in Fig. 1, and the general ex-

pression for the magnetic field radiated is

$$H_1 = \frac{H}{d}\sqrt{[(\cos^2 \alpha + \sin^2 \alpha \sin^2 \beta)]} \quad .. \quad (1)$$

Along the ground where $\beta = 0$ this reduces to the ordinary cosine law

$$H_{1(\beta=0)} = \frac{H}{d} \cos \alpha \quad .. \quad .. \quad (2)$$

and the field passes through zero when the plane of the coil is perpendicular to the direction OR.

When, however β is not zero the radiated field is never zero, whence it is shown that signal minima only and not a zero of intensity will be observed when the plane of the coil is perpendicular to OR. This indicates that absolute zeros are unobtainable in the air when receiving from a beacon on the ground.

(*b*) *Reception of Direct and Indirect Waves from Rotating Coil Transmitter.*—The conditions are shown in Fig. 2, and the general expression for the total effective field acting on a vertical aerial at R is given as

$$H_R = H_1 + (H_2 + H_3) \cos \beta$$

$$H_R = \frac{K_1 H_m}{2l} \cos \omega t \cos \alpha + \frac{K_2 H_m}{2\sqrt{(l^2 + h^2)}} (1 + \rho_v) \cos \beta \cos (\omega t + \phi_1) (\cos^2 \alpha + \sin^2 \alpha \sin^2 \beta)^{\frac{1}{2}} \quad .. \quad (5)$$

where K_1 is a factor for ground attenuation, K_2 for attenuation at the deflecting layer and ρ_v is the coefficient of reflection of the ground. In daytime when $K_2 = 0$, this reduces to the form of (2) and single values are obtainable, *i.e.*, correct bearings are observed. At night, however K_2 will not in general be zero, so that when the coil is at right angles to OR the received signal intensity is not zero and is not necessarily passing through a minimum.

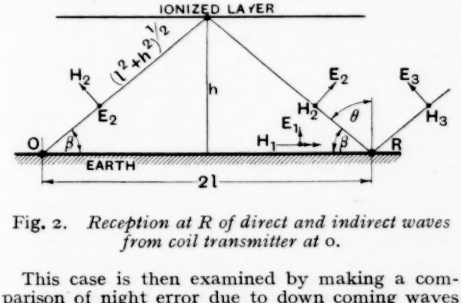


Fig. 2. *Reception at R of direct and indirect waves from coil transmitter at* O.

This case is then examined by making a comparison of night error due to down coming waves with a rotating beacon and with an ordinary direction-finder, employing figures and constants which the author's previous work have proved to be applicable in the latter case.

It is shown that under similar conditions and for transmission overland or sea, observations made with the rotating beacon are liable to errors of the same order as those experienced in the use of a closed coil direction-finder.

(2) Double Rotating-coil Transmitter.

The arrangement suggested is after the manner of the directional receiving system described by H. T. Friis,* employing two co-planar coils operating differentially as in Fig. 3.

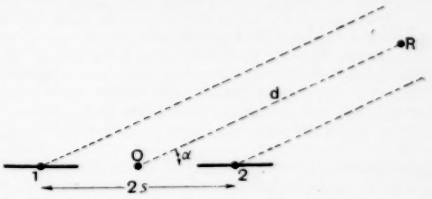


Fig. 3. *Transmitter formed of two co-planar coils about a central vertical axis at* O. *Receiver at R, distance d, orientation* α, *and elevation* β.

(*a*) *General Equations for Radiation.*—The expression for the field intensity is now of the form

$$H_{R(\beta=0)} = \frac{KH_m}{d} \cos \alpha \{\sin (\omega t - \chi) - \sin (\omega t + \chi)\}$$

$$= \frac{KH_m}{d} \cos \alpha \, . \, 2 \cos \omega t \sin \chi \quad .. \quad (7)$$

From analysis of this the author concludes that the signal minimum with the double coil system will not be so sharp as with the single coil.

On the other hand if the receiver is raised so as to subtend an angle of elevation β at O the field is of the form

$$H_R = \frac{KH_m}{d} 2 \cos \omega t \sin \chi (\cos^2 \alpha + \sin^2 \alpha \sin^2 \beta)^{\frac{1}{2}} \quad (8)$$

and the author shows that true signal zeros will be observed when receiving in the air from such a system in daytime.

(*b*) *Reception of Direct and Indirect Waves.*—Treated in the same manner as in section 1 (*b*), the expression for the total effective field is given as

$$H_R = \frac{K_1 H_m}{2l} \cos \alpha \, 2 \cos \omega t \sin \chi + \frac{K_2 H_m}{2\sqrt{(l^2+h^2)}} (1+\rho_v) \cos \beta \, . \, 2 \cos (\omega t + \phi_1) \, . \, \sin \chi \, . \, (\cos^2 \alpha + \sin^2 \alpha \sin^2 \beta)^{\frac{1}{2}} \, . \quad (9)$$

From this it is shown that, while the time of occurrence of minimum giving the correct observed bearing remains unaltered during all conditions of night effect and down coming waves, other secondary minima may be obtained, the observed bearings on which may be in error by the same amounts as those obtained with a single-coil transmitter.

(3) The Adcock Aerial System as a Transmitter.

The use in reception of the aerial system due to F. Adcock has already been described by the present author and R. H. Barfield,† where it is shown to provide a valuable means for eliminating night errors in direction finding. The system may be

* *Proc. I.R.E.*, 1925, Vol. 13, p. 685.

† *J.I.E.E.*, 1926, Vol. 64, p. 831, abstract in *E.W. & W.E.*, June, 1926.

regarded as a pair of spaced vertical aerials with the currents flowing in opposite phase, as in Fig. 4.

(*a*) *General Equation for Radiation.*—This is shown to be of the form

$$H_R = \frac{KH}{d} \cos \beta \,.\, 2 \cos \omega t \sin \chi \quad .. \qquad .. \quad (10)$$

From this it is shown that there is no radiation in the plane perpendicular to the plane of the two aerials, this being true for all values of β.

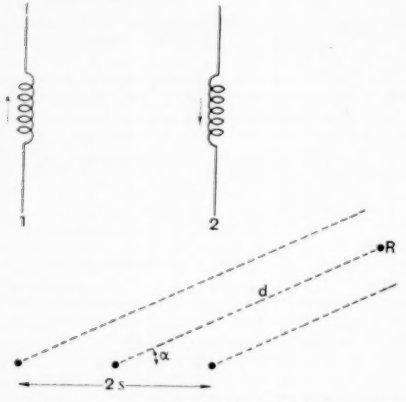


Fig. 4. *Arrangements of pair of vertical aerials as a transmitter on the Adcock system.*

(*b*) *Reception of Direct and Indirect Waves from the Adcock Transmitter.*—The expression for the resultant field is now of the form

$$H_R = \frac{K_1 H_m}{2l} 2 \cos \omega t \sin \chi + \frac{K_2 H_m}{2\sqrt{(l^2+h^2)}} (1+\rho_v)\cos^2\beta$$
$$2 \cos (\omega t + \phi_1) \sin \chi \quad .. \quad (11)$$

and it is shown that the condition for the direct and indirect waves to interfere is independent of α and therefore of the rotation of the transmitter. It is, in fact, simply the condition which produces fading as ordinarily observed on wireless transmitters.

It is therefore concluded that with such a transmitter the signal intensity at the receiver will pass through the zero whenever the plane containing the aerials is perpendicular to the direction of the receiver. This is the only zero to be observed under any conditions of downcoming waves, and bearings will remain correct throughout all conditions of night effect in transmission.

DISCUSSION.

A general discussion on the subject of rotating beacon transmitters followed the reading of the papers.

The discussion was opened by **Capt. Kennedy-Purvis, R.N.,** who spoke as one concerned with using the device at sea. The use of directional wireless in navigation was very important and navigators must have confidence in the system employed. Bearings taken by shore direction-finding stations were more accurate than those taken afloat. A definite fix could only be made by the co-operation of two shore D.F. stations or by a ship taking bearings on two shore stations. The beacon method necessitated nothing but the ordinary wireless gear of the ship and represented a great advance. He hoped the authorities concerned would press the rotating beacon which he regarded as being especially useful to the captain of the small ship.

Mr. Davie said that although the rotating beacon was at first sight very attractive, it could only remain so if it proved economical and efficient. The economic aspect was the final arbiter. He then dealt with the difficulty of supplying calibration charts of each such beacon station to all the ships that might use it and of the possible need for re-calibration. Were causes of error in the calibration of the beacon due to site? Having regard to the results, he thought there were two conditions to be fulfilled, (1) An ideal and symmetrical site, (2) a homogeneous path round the whole of the arc of operation. These have considerable bearing on the economic aspect. The ideal site would be a ship out on the water; the next best a small island such as Lundy or one of the Scillies. On the mainland he could think of few places except perhaps Dungeness and Portland Bill which might be suitable. For the ideal station the capital cost and maintenance charges would be high for the number of beacons required as compared with the use of D.F. on ships receiving the ordinary coastal transmissions.

Dr. J. Robinson did not agree with this pessimistic view of the results. The people who had developed the beacon were to be congratulated on its success. The rotating beacon was first intended for aircraft. There was no trace of night error in working with aircraft and no trace of effects due to site, but the matter of night error must be investigated by the Air Ministry. He agreed with Capt. Kennedy Purvis as regards its valuable aid to marine navigation. The results quoted by Dr. Smith-Rose were very good, especially over sea. Aircraft, however, remained the most important need, and he hoped the Air Ministry would have confidence to build a bigger beacon station with a greater range up to 500 or 600 miles. As regards improvement of the beacon transmitter he agreed that the Adcock aerial was no doubt ideal. The present type of beacon transmission was undoubtedly the best available, compared with the American system or with the short wave beam. The latter he did not consider fit for application to navigation.

Dr. S. H. Long first dealt with the similarity of the problem in transmission and reception. In reception he had already found the single coil direction-finder best. The use of this form of D.F. reception was important on the British coast where the carrier waves of B.B.C. stations could be used as a fixed beacon transmission. Would it be practicable with the rotating beacon to utilise a vertical aerial in conjunction with the frame and work on a heart-shaped polar curve of radiation? With reference to the matter of site, he quoted a case of a D.F. set where errors were observed when it was near the edge of a hill and were removed

on transferring the set much further back from the edge. He did not agree that the rotating beacon was equally useful to ships as it was to aircraft. The use of D.F. at sea was important in the prevention of collision. A considerable number of beacon stations would be necessary and the cost would be prohibitive.

Mr. R. H. Barfield was glad to see the dual sides of development and testing for results presented by the personnel responsible for the different work. In the development he thought that the fitting of all the apparatus inside the loop was a critical step in the improvement of antenna effect. The second paper gave very good information on the performance of the rotating beacon, and the authors had, from his personal knowledge, worked very hard in the accumulation of the data given in the results.

Capt. P. P. Eckersley asked whether the system had any great advantage as compared with that of ships obtaining bearings from two land D.F. stations. The ether was very full and it was undesirable to add any other steady transmissions. Working to coast D.F. stations would not be heavy in clear weather, and he favoured this even if it led to a congestion at these stations in foggy weather. Was the system described in practical use or was it merely in the state of test ? What happens with the Inch Keith short wave system ? There was much more room for the ether on shorter waves.

Mr. R. A. Wilmotte said that more figures on the range of the loop would be interesting. The fact shown in the third paper that generally the beacon transmitter was subject to the same effects as ordinary D.F. was in accordance with Sommerfeld's reciprocal theorem. Hence arose the advantage of the Adcock system. From consideration of various arrangements of spaced coils, he did not consider that any such arrangement could possibly give the same effect as the Adcock aerial.

Mr. Boyd said that the question was largely a matter of money. There were always ships with no D.F. fitted, and he hoped that the development of the rotating loop would not hinder the development of ship direction-finding. With reference to Capt. Eckersley's remarks as to shore D.F. stations, these were expensive, costing about £6,000 to instal and £4,000 a year to run. He sought for information as to the power necessary to work the beacon, especially as regards the change of power necessary to get equal range on other wavelengths.

Dr. Smith-Rose (participating in the discussion) said that improvement in the uniformity of speed of the Gosport beacon had been effected by the use of a tuning fork and phonic motor. The order of steadiness was now such that there was less than 1 sec. error in three hours' continuous running.

The authors briefly replied to certain of the points raised in the discussion, leaving more extended replies to be communicated.

Mr. Gill considered that the few rotating beacons necessary would be more economical than coast D.F. stations. The matter of site was under investigation. Night tests in the air had shown no great errors as were revealed on the ground.

Dr. R. L. Smith-Rose thought that errors must exist in the air and that Sommerfeld's reciprocal theorem was equally applicable here. He showed a slide illustrating the position of an aircraft relative to the ground and to the deflecting layer, when the machine was at some distance from the transmitter. It was clear that the machine was effectively under the same conditions as those at the surface of the earth. He also showed a slide illustrating the arrangement of stop watch dials to read directly in degrees when started from either the N. or from the E. reference transmission.

On the motion of the Chairman (Lt.-Col. A. G. Lee) the authors were cordially thanked for their papers.

The Physical Society's Exhibition.

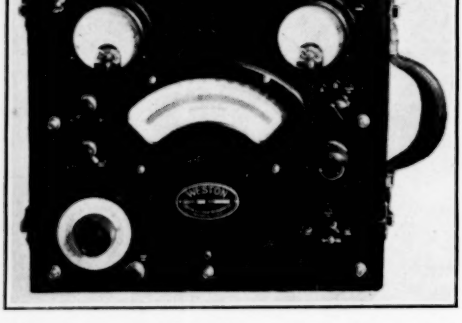
Matters of Wireless and Laboratory Interest.

THE Eighteenth Annual Exhibition of the Physical Society and the Optical Society was held this year at the Imperial College of Science and Technology, S. Kensington, on 10th, 11th and 12th January. Following the arrangement adopted last year, admission on the first two days was by ticket only, while on the third day the Exhibition was freely open to the public. An additional session was held from 10 a.m. to 1 p.m. on 11th January, admission to which was available only to Fellows of the Societies on a special ticket.

As has been the case in recent years, the Exhibition was again characterised by the large number of exhibits of great interest to the wireless worker, as well as to the laboratory experimenter in wireless or in the many branches of physics which now border so closely on wireless practice.

ELECTRICAL MEASURING INSTRUMENTS.

Electrical measuring instruments, *e.g.*, Ammeters, Voltmeters, Milliammeters, etc., were, as usual, well represented, the exhibits showing the improvements in detail which are steadily proceeding.



Valve characteristic recorder, manufactured by Weston Electrical Instrument Company. A.C. resistance magnification factor and mutual conductance are shown as dial readings.

CROMPTON, PARKINSON, LTD. (Chelmsford and Guiseley) exhibited a range of A.C. and D.C. instruments, including the popular "All Test," D.C. Portable Multi-range Testing Set, and the "A.C. Test" in the form of a portable A.C. multi-range ammeter and voltmeter.

ELLIOTT BROS. (LONDON), LTD., showed a new current transformer for provision of a large number of A.C. ranges, their Multiversal Testing Set, and a pleasing portable moving coil galvanometer. Another interesting feature was a range of thermo-couples in which the heater is insulated from the couple itself.

EVERETT EDGCOMBE & CO., LTD., had on view the Warren Synchronous Motor, a very serviceable little machine with a wide range of uses, precision moving-iron ammeters and voltmeters, with a nickel-iron current transformer for various single and multi-ranges. Instruments for use at radio frequencies included patterns of the thermo-expansion and thermo-couple types, while for recording, graphic instruments of the "Inkwell" pattern and of the "Relay" pattern were on view, capable of recording with a maximum scale of 150μA.

The exhibits of EVERSHED & VIGNOLES, LTD., included the well-known lines of this firm, more especially in connection with resistance testing instruments of the Megger, Meg and Ducter class.

THE FOSTER INSTRUMENT CO. showed high precision milliammeters and millivoltmeters in portable forms with the "Resilia" system of spring mounting, giving a combination of high sensitivity and ruggedness in use.

NALDER BROS. & THOMPSON, LTD., exhibited an extensive range of instruments, including induction type instruments of nearly circular scale.

Circular scale instruments were also a feature at the stand of the RECORD ELECTRICAL CO., LTD., including a model especially suitable for laboratory or lecture demonstrations.

THE STONEBRIDGE ELECTRICAL CO., LTD., had on view an electrostatic voltmeter up to 15,000 v., standard laboratory instruments, portable multi-range precision instruments and miniature recording instruments for various purposes.

An interesting instrument of MESSRS. ERNEST TURNER (High Wycombe) was an A.C. voltmeter employing the copper oxide rectifier described in our last issue. This is used in conjunction with a D.C. movement to give an A.C. voltmeter with three scales of 1, 10 and 100 v. of practically linear openness.

THE WESTON ELECTRICAL INSTRUMENT CO., LTD., had an extensive display of laboratory instruments of high accuracy and standard portable testing instruments, miniature precision meters and numerous instruments of radio application, including thermo-ammeters and galvanometers and small 2-inch panel instruments. Two-valve testing sets were also on view, one for complete test of the valve in the laboratory and the other for test of receiving sets in actual working conditions.

LABORATORY EQUIPMENT.

Laboratory apparatus of the high standard associated with the Exhibition was also well represented, and many high-grade instruments of the radio laboratory were to be seen.

At the stand of the CAMBRIDGE INSTRUMENT CO., LTD., an interesting feature was a Duddell Oscillograph of simple projection pattern, well adapted for lecture demonstration or for any non-recording purpose. A high voltage Oscillograph was also shown, capable of use up to 75,000 v. Another interesting instrument was a Schering bridge for power factor and permittivity measurement, while the Capacitance Bridge and the Mutual Inductometer, due to Mr. A. Campbell, were also attractive instruments to the wireless worker.

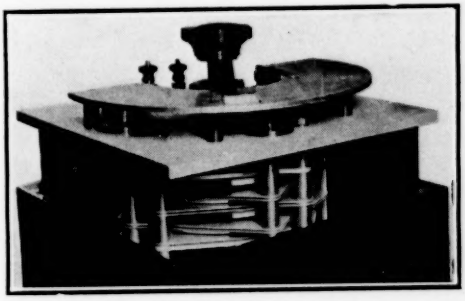
GAMBRELL BROS., LTD., were showing a new pattern laboratory condenser and a mirror galvanometer with interchangeable coils for different sensitivities. Of more purely wireless interest were this firm's range of mains receivers using A.C. or D.C. mains for all supplies.

J. J. GRIFFIN & BAIRD & TATLOCK, LTD., displayed a moving coil galvanometer with self-contained lamp and scale, and also with interchangeable suspensions, while an Ayrton Mather pattern of reflecting instrument also included this feature.

W. G. PYE & Co. (of Cambridge) showed a large range of laboratory apparatus, including electrically maintained forks, resistance boxes, galvanometers, etc.

THE SILVERTOWN COMPANY, while showing chiefly matters of line telegraph interest, had several features of wireless interest in the way of transformers, telephones, loud-speakers, etc.

H. W. SULLIVAN & Co., LTD., had on view a very extensive range of laboratory apparatus, largely of wireless interest. This included their



The Sullivan-Griffiths Precision condenser, for use in accurate wavemeters. Adjacent dielectric gaps are electrically in series instead of parallel, and are also complementary.

Standard Multivibrator Wavemeter (due to Dr. D. W. Dye), variable air condensers of great precision and fixed value air condensers. Amongst condensers the new " Sullivan-Griffiths " precision variable air condenser (described in our last and present issues) was on view for the first time, and a demonstration was given of its constancy of capacity on varying the distance between the fixed and moving plates. Other interesting apparatus included various oscillating wavemeters (one for 10 to 100 metres), oscillators for audio frequencies, non-reactive bridges and ratios, and a Schering bridge for power factor and S.I.C. measurements.

H. TINSLEY & Co. showed a non-generating wavemeter to the design of Dr. D. W. Dye, a standard condenser, portable galvanometers of the self-contained mirror type for A.C. and D.C., variable inductometers, non-reactive bridges, ratios, resistance boxes, etc.

WIRELESS ACCESSORIES, PARTS, SETS, ETC.

Several of the stands were devoted to articles of purely wireless interest.

At the stand of the MULLARD RADIO VALVE CO. and MULLARD WIRELESS SERVICE, LTD., were a wide range of P.M. valves and valves of the transmitter class in the power amplifier, modulator and rectifier forms. This firm's assembly of the screened grid valve was also on view for the first time, this valve fitting into a standard valve holder, where the anode point R becomes the lead to the screen, while the actual anode is lead to a separate terminal on the top of the valve. An amplification factor of 200 is quoted. Another feature of great interest also displayed for the first time, was a Pentode or five electrode valve, this having a still extra grid (placed between the screen and the anode and joined internally to the filament). In the case of this valve the ordinary anode pin is used as anode while the screen is led to a terminal in the side of the valve cap. This valve is claimed to have an amplification factor of 60 to 100 and to give exceptionally good output with smaller grid bias than the usual type of small power-valve. Other well-known Mullard accessories, resistances, grid leaks, loud-speaker, etc., were also on view.

THE MARCONI-OSRAM VALVE CO., LTD., had on show a very complete display of valves of all sizes and for all purposes, including the now well-known screened valve of this firm, and a selection of short-wave valves for transmitting and receiving, certain of these being of the patterns in use at the Beam Stations.

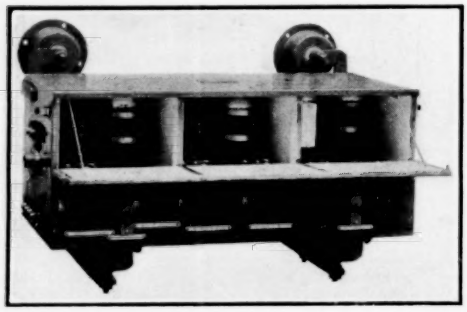
Marconi valves were also on display at the stand of the MARCONIPHONE CO., LTD., along with a wide range of receivers. Two of these included the screened valve, one set being in the form of a constructional receiver, while the other had three H.F. stages with these valves. Other interesting receivers included an eight-valve supersonic with single control. The Marconiphone pattern of Rice-Kellogg loud-speaker was also on view, and two new reed-driven cones.

At the MARCONI WIRELESS CO.'s stand were shown a short-wave receiver and a Marconi press receiver for " all-world " use, while a time signal portable receiver for the use of surveying parties was also on view.

The RADIO COMMUNICATION CO. had a single exhibit in the form of their automatic call device, which was shown in operation, responding to three dashes each of four seconds.

THE DUBILIER CONDENSER CO., LTD., showed typical examples of their very extensive range of condensers for all wireless purposes. Notably a precision variable air condenser and several forms of standard condensers variable in steps. Improved forms of Mansbridge condensers were on view along with a new form of mica condensers for capacities of .02 to .3μF. An anti-interference unit, designed

primarily for use in conjunction with small domestic motors, such as fans, etc. (especially when such apparatus is in use close to the wireless receiver), was also an interesting accessory. Amongst other accessories noted were a mica insulator and an R.C. coupling unit, while an electrostatic pickup was demonstrated in operation on a Rice-Kellogg loud-speaker.



Marconi Four-valve Short-wave set, in which one stage of neutralised H.F. amplification is employed. A doublet aerial is connected to a feeder box (not shown) which allows the receiver to be operated at almost any distance.

The stand of THE EDISON SWAN ELECTRIC CO. was devoted entirely to valves of all classes and to the well-known Pointolite lamp, now shown in its latest form.

THE IGRANIC ELECTRIC CO., LTD., showed an extensive range of radio components, a new component being a " Lokvane " square law condenser. Outfits for definite set construction included a " Neutro-Regenerative " short wave amplifying kit, a 7-valve supersonic kit, etc. A range of eliminators for D.C. and A.C. work and other wireless set components were also on view.

PHILLIPS LAMP CO., in addition to a number of X-ray tubes, had on view a new metal hot cathode rectifier valve, suitable for voltages up to 130,000 v.

VENNER TIME SWITCHES, LTD., showed their " Venanto " time switch for wireless broadcast receivers, along with a range of selenium cells.

Amongst other matters of general wireless interest were the resistances and controls of MESSRS. ISENTHAL & CO., LTD., and of THE ZENITH ELECTRIC CO., LTD., a very complete range of batteries for L.T. and H.T. at the stand of the FULLER ACCUMULATOR CO., and the rotary transformer of THE ML MAGNETO SYNDICATE, LTD.

RESEARCH AND EXPERIMENTAL SECTION.

Following the lines introduced last year, a Research and Experimental Section again showed recent developments, lecture experiments, historical exhibits, etc.

In this section the most interesting features from a wireless point of view were a new primary wet cell by MR. A. M. CODD, using zinc and carbon with a solution of ferri-chloride. This is claimed to be suitable for dull emitters as well as for domestic appliances, etc.

The G.E.C. RESEARCH LABORATORIES showed a new type of photo-electric cell, a simple means of using photo-electric cells; and a method of maintaining a valve filament at constant voltage, whether the anode is energised or not.

MR. E. B. MOULLIN showed three new forms of high-range thermionic voltmeters, one of particular interest giving measurement of either peak or R.M.S. voltage.

DR. D. OWEN demonstrated the use of a magnetron to show the tune of establishment of current in an inductive field.

Dubilier Wavemeter, in which the glowing of a neon lamp indicates resonance.

THE GRAMOPHONE CO., LTD. (RESEARCH DEPT.), had a highly interesting exhibit showing the application of electrical analogies to acoustic design. The sound box shown was of the latest form, with its electrical equivalent circuits, both treated from the point of view of a band-pass filter network.

Abstracts and References.

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PROPAGATION OF WAVES.

DIE STÖRUNG DES ELEKTROMAGNETISCHEN FELDES EINES SENDERS DURCH GEBÄUDE UND ÄHNLICHES (The disturbance of the electromagnetic field of a transmitter by buildings, etc.).—S. Klimke. (*Elekt. Nachr. Technik*, 4, pp. 458-482, November, 1927.)

Although this investigation of the action of buildings, etc., on the development of a transmitter's electromagnetic field deals mostly with quite local influences, the knowledge of the field structure obtained is of practical importance, particularly since the coming of broadcasting, in showing how receivers located in the vicinity of such a disturbed electromagnetic field are affected. The paper is divided into three sections, dealing firstly with theory, then with methods of measurement, and lastly with the measurements themselves.

I.—THEORY.

A wave developing undisturbed in vacuo or air possesses an electric component E and a magnetic component H which are in phase and perpendicular to one another and to the direction of propagation. From an absolute point of view $E = H$. This follows from the condition that, for each point of the field, the energy content of the electric must equal that of the magnetic field. If both components are given in E.M.U., we have the constant relation

$$E = cH.$$

In practice only H is given in E.M.U., in gauss, the electric component being given in V/m. Employing these two units, we obtain the equation

$$H \text{ (gauss)} = \frac{10-4}{3} E \ (V/m).$$

These equations, however, only hold good when there are no conductors in the field: if these are present $E \neq H$ and one conductor can no longer be determined from the other. To find the new structure of the field, the effect of a conducting system on both the electric and magnetic fields is calculated at length. It is found, in general, that while a conductor screens its immediate surroundings from the electric field, absorbing, so to speak, the field within itself, the magnetic field only suffers change of direction, and is not attenuated except by a loop-like or latticed structure.

II.—METHODS OF MEASUREMENT.

To confirm the theoretical deductions experiments were carried out in the field of the Dresden transmitter, usually at a distance of 9 to 10 wavelengths away, though some tests were made quite near, within a quarter wavelength. The near electric measurements were made with a Seibt drawn-out coil, and the more distant ones with a small elevated antenna surmounted by a metal umbrella for concentrating the capacity, the copper-plated instrument box serving as counterpoise. The magnetic measurements were made with a frame aerial. Photographs of the apparatus are shown. The diagram of the circuit-arrangement is reproduced in Fig. 1 below:—

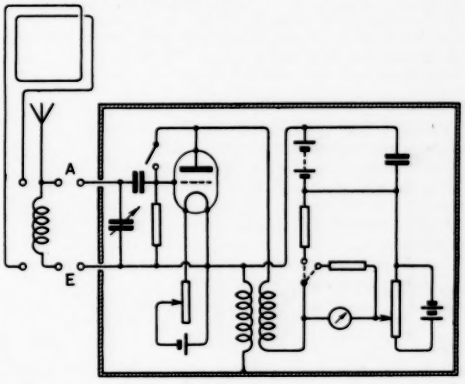


Fig. 1.

The apparatus was calibrated as a whole by means of a wire extended about 10 metres above the ground in which a known tension was produced. The calculation of the field-strength is explained in detail.

III.—THE OBSERVATIONS.

The results are given of measurements made in the vicinity of a large number of different objects: the field found in the case of an iron lattice arc lamp-post is shown in Fig. 2 below:—

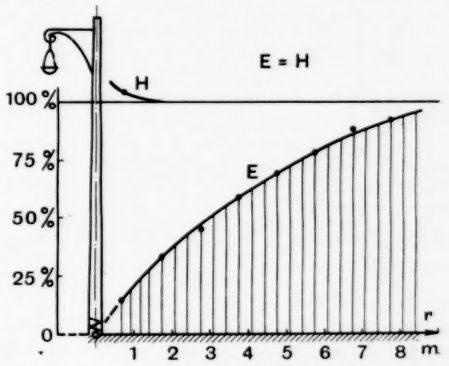


Fig. 2.

and compared with the theoretical disturbed electric and magnetic fields (Figs. 3 and 4).

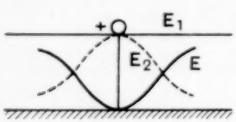


Fig. 3.

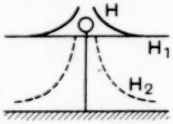


Fig. 4.

With wooden masts and sheds, no effect on the magnetic field was found and only a slight effect on the electric field, after rain, when the apparatus was brought quite close up (Fig. 5).

In the case of trees, no effect was found unless the apparatus was very near the tree, when an attenuation of the electric field by about 20 to 30 per cent. was generally found, independently of the size of the tree: no magnetic effect was ever observed. The measurements were carried out in March when the trees were still bare.

Besides these instances of a "pure dipole effect," examples are given of systems where the magnetic field is also affected, which include a large cable reel and the wire netting around a tennis ground.

Concerning the conductivity of buildings, those made of brick are found to be quite moderate conductors, as seen in the following diagram :—

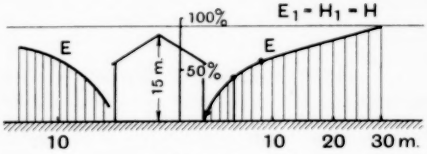


Fig. 5.

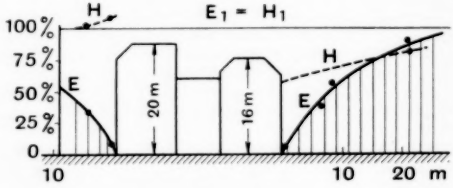


Fig. 6.

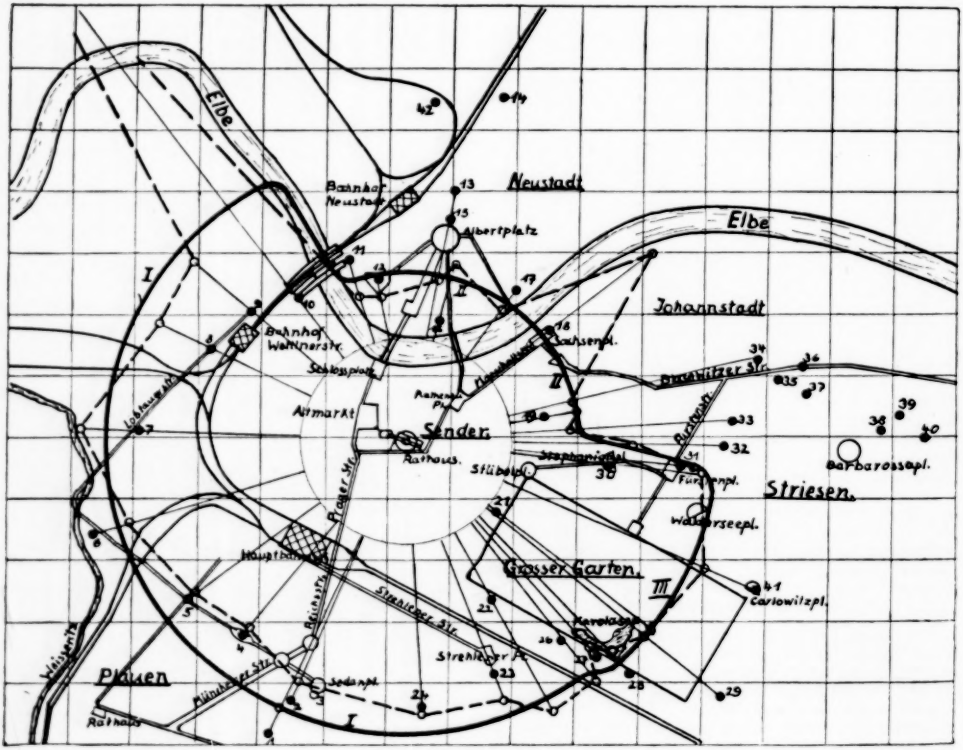


Fig. 7.

and those built of iron and concrete to affect both electric and magnetic fields as shown in Fig. 6.

Houses containing much iron act like a Faraday cage and prevent the electric field penetrating, particularly to the lower storeys: the electric field, as it were, steps over the houses; while the magnetic field penetrates to the ground, only its direction being distorted, except when it is attenuated by conducting loop-like or latticed structures.

Measurements made quite close to the Dresden transmitter, within its static field, likewise confirm the theoretical conclusions. The propagation curve of the electromagnetic curve is shown in **Fig. 7.**

The better propagation over the gardens on the right shows that houses absorb more field energy than trees. The low field values measured beyond the Elbe and partly also in an easterly direction are attributed to geological and ground-water conditions or a directivity of the transmitting antenna.

MESSUNGEN DER ELEKTROMAGNETISCHEN FELDSTÄRKE ZUR BESTIMMUNG DER REICHWEITE EINES RUNDFUNKSENDERS (Measurements of electro-magnetic field-strength to determine the range of a broadcast transmitter). (*E.T.Z.*, 48, pp. 1778-1779, 1st December, 1927.)

Abstract of a paper by S. Lemoine in *Tekniska Meddelanden från Kungl. Telegrafstyrelsen*, 1927, Nos. 2 and 3, p. 9.

In the summer of 1926, the Swedish Telegraph Department carried out measurements of the field-strength of the Karlsborg transmitting station, in different directions and at varying distances, with a view to determining the damping with changing conditions of the ground in the centre of Sweden, and estimating the range for detector reception of the Motala broadcast transmitter, then in course of construction. The observations were made chiefly along five radial lines, as shown in the map (Fig. 1).

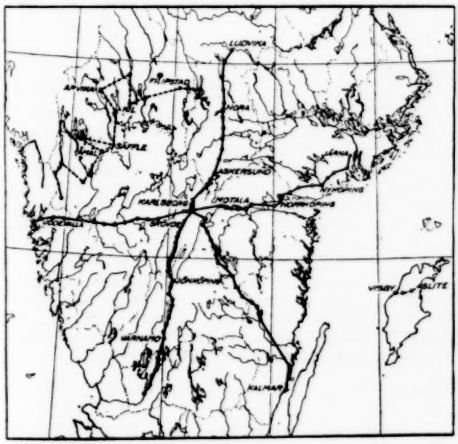


Fig. 1.

The experiments were based on Austin's formula (although this assumes transmission over water and in daylight) generalised in the following form :—

$$I_2 = 120\pi \frac{I_1 h_1 h_2}{d\lambda R} e^{-\frac{kd}{\sqrt{\lambda}}}$$

where, for a concrete case, all quantities are known except the damping k. For convenience, measure-

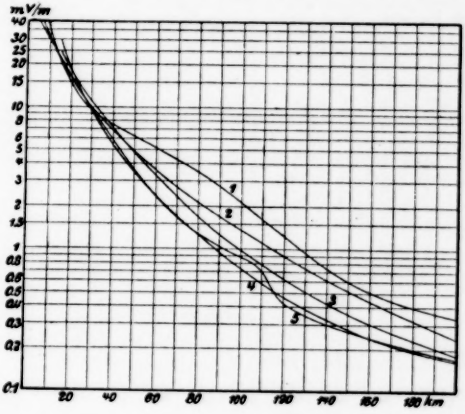


Fig. 2. 1. *Direction of Jönköping.*
2. ,, ,, *Uddevalla.*
3. ,, ,, *Nyköping.*
4. ,, ,, *Kalmar.*
5. ,, ,, *Ludvika.*

ment was not made of the current strength in the receiving antenna I_2, but of the E.M.F. per unit

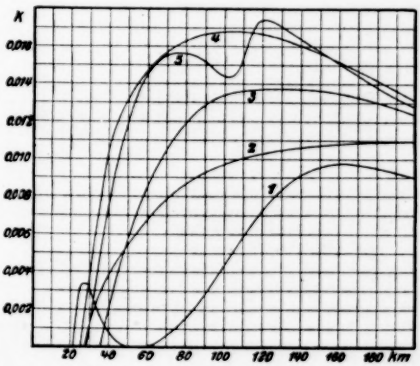


Fig. 3.

length E. Writing the equation as follows :—

$$E = \frac{I_2 R}{h_2} = 120\pi \frac{I_1 h_1}{d\lambda} e^{-\frac{kd}{\sqrt{\lambda}}}$$

or, inserting the data for Karlsborg in amp. + kM, we have

$$Ed = 120\pi \frac{8{\cdot}5 \cdot 0{\cdot}130}{1{\cdot}365} e^{-\frac{kd}{\sqrt{1{\cdot}365}}}$$

After plotting the readings on logarithm paper, the damping k can be calculated. The mean values

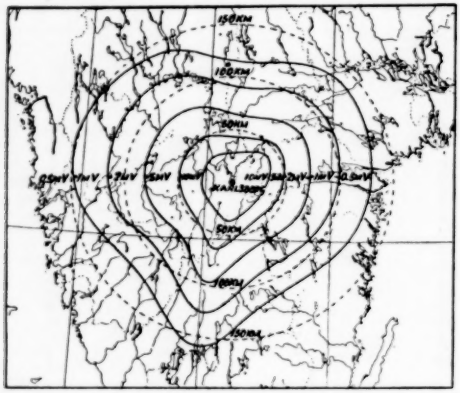


Fig. 4.

of the field-strengths measured are compared in Fig. 2.

The ground conditions are so unhomogeneous that no equation can be drawn up that takes account of all of them. Fig. 3 shows the variation of the damping constants as obtained from these experiments, and Fig. 4 the equipotential curves for the field-strength of the Karlsborg transmitter.

THE ATTENUATION OF WIRELESS WAVES OVER LAND.—R. H. Barfield. (*E.W. & W.E.*, 5, pp. 25-30, January, 1928.)

Abstract of paper given before the Wireless Section, Institution of Electrical Engineers, 7th December, 1927.

DISCUSSION ON LONG-DISTANCE RECEIVING MEASUREMENTS AT THE BUREAU OF STANDARDS IN 1925 (L. W. AUSTIN).—K. Sreenivasan. (*Proc. Inst. Radio Engineers*, 15, pp. 1002-1003, December, 1927.)

RAUMSTRAHLUNG VON HORIZONTAL-ANTENNEN (Space Radiation from Horizontal Antennæ). —A. Meissner. (*Elekt. Nachr. Technik*, 4, pp. 482-486, November, 1927.)

A paper read at a meeting of the Heinrich Hertz Society, 5th September, 1927.

One of the most interesting problems of short-wave technique is the employment of horizontal antennæ and polarisation at transmission. Horizontal antennæ present the more striking innovation, evidently breaking with tradition in that all connection with the earth is entirely dispensed with, the whole radiation being quite detached from the earth's surface straight from the transmitter. The significance for wireless technique of the introduction of horizontal polarisation is shown by the widely distant and independent consideration made of the problem: first, by Alexanderson in America, then shortly afterwards by German experimenters, and in France Levi has a patent for horizontal antennæ dating from the same time. In Germany work was concentrated on horizontal polarisation and developed in a different direction from that in America and France.

Although the employment of horizontal antennæ and polarisation appears less specially remarkable when the idea of the transference of energy by pure space radiation has been grasped, the fact that when a horizontally polarised beam is sent out it must be received not as horizontally but vertically polarised is a new and for the present inexplicable phenomenon.

In the Telefunken Company's first experiments with horizontal transmitting antennæ, more than two years ago, horizontal receiving antennæ were always ordered for Buenos Ayres, but it was repeatedly reported that they would not work, and that reception could be effected only with a vertical antenna. Evidently a rotation of the plane of polarisation was taking place, similar to that found in optics, for which no unambiguous explanation has been given. We have to content ourselves with the apparently pretty general fact, that the plane of polarisation of a polarised radiation tends to place itself perpendicular to the surfaces of bodies over which it glides, if the bodies partly absorb the radiation or arrive at oscillating in resonance with it. Curves taken from a paper by Heising, Schelling and Southworth are reproduced, which show the gradual transition from horizontal to vertical polarisation with distance.

In the case of beam projectors employed by Marconi to concentrate the radiation, distinction has to be drawn between projectors for horizontal and those for vertical polarisation. With both projectors concentration in a horizontal plane is equally good and easy to obtain. With the vertical projector it is secured by placing several vertical antennæ, oscillating in the same phase, side by side in a plane, and with the horizontal projector by combining several horizontal antennæ oscillating in like phase, in a line. In both cases the greater the number of antennæ the greater the concentration. The gathering up of the radiation, concentrated in a horizontal plane in this way, into a beam—the concentration in a vertical plane—takes place in a different manner with the two projectors: in the case of the vertical projector it is effected by arranging several antennæ, a half-wave in length, oscillating in the same phase, one above the other, while with the horizontal projector this gathering up is brought about by constructing a parabolic reflector around the antenna. These methods of concentration were illustrated in the author's article in the *Zeitschrift* for September (these Abstracts, December, 1927, p. 766; *Proc. Inst. Radio Eng.*, 15, 11, p. 928) which should be referred to for further description of the investigation.

PROPAGATION OF SHORT WAVES DURING A SOLAR ECLIPSE.—E. J. Alway. (*Proc. Inst. Radio Engineers*, 15, pp. 998-1001, December, 1927.)

Special watch was kept at the Heliopolis receiving station, Egypt, in the early morning of 29th June,

to observe the effect of the solar eclipse on the transmission of the 40–45 metre waveband.

After giving some notes of stations heard both in Europe and America, the writer concludes by assuming that, at least locally, a solar eclipse produces a pseudo-night-effect, this effect beginning with the eclipse, but finishing before it: that is, when the eclipse occurs in the morning.

THE RELATION OF RADIO RECEPTION TO SUNSPOT POSITION AND AREA.—G. W. Pickard. (*Proc. Inst. Radio Engineers*, 15, pp. 1004-1012, December, 1927.)

Communication from the International Union of Scientific Radio Telegraphy.

The purpose of this paper is to show that the central passage of sunspots does not exactly coincide with the associated reception disturbances and that the interval between the transit of the sunspots and the reception change varies both with the area of the sunspot group and with the period taken for investigation.

The results are represented graphically and discussed. The curves clearly show that the connection of reception with sunspots is far less intimate than its relation to magnetism, which is so definite as to require the conclusion that disturbances of reception and terrestrial magnetism arise from a common and nearby cause: an electrical change in our atmosphere. On the other hand, even when position as well as area is considered, the connection between individual sunspot groups and reception is quite insufficient to show that we are here dealing with cause and effect.

INFLUENCE DES SURFACES DE DISCONTINUITÉ ATMOSPHÉRIQUES SUR LA PROPAGATION DES ONDES COURTES (Influence of the atmospheric surfaces of discontinuity on the propagation of short waves).—G. Henri Huber. (*Comptes Rendus*, 185, pp. 934-936, 7th November, 1927.)

A series of observations was made in France on the service of meteorological transmissions from the dispatch boat, *Ville-d'Ys*, during its cruise to Norway and Iceland. The transmissions were made on 65 and 24 metres simultaneously and from the observations, carried out regularly six times a day, the following conclusions are drawn:

Surfaces of atmospheric discontinuity form an obstacle to the propagation of short waves; this is most distinct for the polar front properly so called, which often presents very sharp discontinuities; moreover, the obstacle is the more serious, the more marked the fraction of the front located between the two stations trying to communicate. In the case of a surface of discontinuity forming two dihedra with the ground, one pointed and the other obtuse, the emission of a station situated in the pointed dihedron is much less obstructed than its reception; it is seen that such a station could quite well not hear its correspondents beyond the front and yet be heard by them. Further, it seems that the nearer one of the two correspondents is to the front, the greater the obstacle presented to propagation.

ATMOSPHERICS.

THE RANGE OF ATMOSPHERICS.—(*Quarterly Journal of the Roy. Met. Soc.*, 53, pp. 327-400.)

A Report from the Committee on the Relation between Atmospherics and Weather.

Although the evidence set forth in this report is too conflicting for any certain conclusion to be drawn on the main issue, namely, the relation between atmospherics and weather, the Committee are of the opinion that the evidence decisively shows:—

(*a*) That the effective range of reception of very many atmospherics, heard on normal broadcast receivers, exceeds 3,000 km. or 1,850 miles, and reaches at least 7,000 km. or 4,500 miles.

(*b*) That there is no evidence of the presence of many atmospherics whose range is less than 200 km.; that such atmospherics, should they exist, never formed so much as 25 per cent. of the distribution on any of the occasions discussed.

(*c*) That the evidence obtained confirms previous experience in showing that cold fronts are of great importance in the origination of atmospheric disturbance.

(*d*) That the seventeen random samples considered in the report demand fuller examination of the meteorological environment.

(*Cf.* Mr. Watson Watt's observations, *Journ. Met. Soc.*, 52, p. 199, these Abstracts, January, 1927, p. 50.)

ATMOSPHERICS AT WATHEROO, WESTERN AUSTRALIA.—J. E. Cairns. (*Proc. Inst. Radio Engineers*, 15, pp. 985-997, December, 1927.)

Of nearly 1,000 atmospheric radiation waveforms observed over a period of nine days at the Watheroo Magnetic Observatory from 20th to 28th March, 1927, the most frequently occurring form was found to be a negative peaked quasi-periodic consisting of three "half cycles," the maximum field-change being associated with the second "half cycle." The mean duration and field-strength of this type, which occurred in 10 per cent. of all cases examined, were 3,458 μs and 0.139 volts per metre respectively. Reconstructed drawings of the most frequently occurring forms are given, as well as reproductions of actual sheets of observations.

The summer "roar" is shown to be most probably due to short-period, small-amplitude, almost continuous ripples, the period lying between 50 and 100 μs and the amplitude being approximately 0.008 volts per metre. The static "rattle" noted by De Groot in the Dutch East Indies is probably due to ripples similar to these.

Negative atmospherics predominated, the only notable positive being an aperiodic of relatively long duration, this form being almost invariably associated with lightning. Quasi-periodics were more numerous than aperiodics, and the peaked form occurred in greater numbers than the rounded. The symmetrical negative peaked aperiodic was noteworthy, because of the shortness of its duration, 786 μ sec. All atmospherics seen on the oscillograph screen were accompanied by a noise in a radio receiver.

Semi-permanent field-changes were fairly numerous, the negative change occurring far more frequently than the positive, the thunderstorms producing these changes being usually over 50 km. distant.

WIRELESS AND METEOROLOGY.—(*Wireless World*, 21st December, 1927, pp. 813-816.)

Account of the observation of atmospherics carried out on the U.S.S. *Kittery*, which enabled the progress of hurricanes in the West Indies to be traced, and conclusively proved Lieut. Kincaid's theory that the strength of static is proportional to the rate of change of atmospheric pressure.

PROPERTIES OF CIRCUITS.

THE STABILITY OF THE TUNED-GRID TUNED-PLATE H.F. AMPLIFIER.—R. T. Beatty. (*E.W. & W.E.*, 5, pp. 3-15, January, 1928.)

THE RELATION BETWEEN PLATE CURRENT AND PLATE POTENTIAL IN THE THERMIONIC AMPLIFIER, DEDUCED FROM THE ORBITAL MOTION OF THE ELECTRONS.—L. E. McCarty. (*Physical Review*, 30, pp. 878-892, December, 1927.)

An expression for the plate current in terms of the grid and plate potentials and geometrical dimensions of a parallel plate type of thermionic amplifier is deduced from the orbital motion of the electrons. The amplifier is assumed to consist of a charged grid of small parallel wires of infinite length situated between two infinite parallel plates at distances from it comparable with the distance between consecutive grid wires, the whole enclosed in a vacuum of such magnitude that the mean free path of the electrons is large in comparison with the distance between the plates. The effect of the space charge is neglected.

Equations giving the force acting on an electron situated at any point in the field due to the charge on the grid and the potential difference between the anode and cathode are derived. These expressions are evaluated and tabulated for various points of the field and the orbits of a number of electrons computed by a process of numerical integration. An empirical relation is found to exist between the distance of the starting points of the electrons, whose orbits turned at a common plane, from the rectilinear projection of a given grid wire on the cathode, and a certain parameter involving the charge per unit length of grid wire, the plate potential, and the geometrical dimensions of the amplifier. Inasmuch as the plate current is determined by the number of electrons reaching the plane where the plate is assumed to be located, before turning back; and since the turning point depends on the starting position of the electron relative to the grid wires, this empirical equation furnishes the required relation between current and plate potential, grid charge, and the geometrical parameters.

Two cases are considered: (*a*) a negatively charged grid, and (*b*) a positively charged grid. On account of the greater practical importance of the first case most of the orbits computed are for a negatively charged grid. After substituting for the charge on the grid in terms of the potentials and capacity coefficients, the final equation for this case, assuming the cathode to be at zero potential and at a distance from the grid equal to the distance between consecutive grid wires, is

$$I_P = I_0\{1 - 2C_1[a(kV_P + hV_G)]^2(aV_P - SV_G) - \mu_0\}^{\frac{3}{2}}$$

where I_0 represents the saturation current, V_P and V_G the plate and grid potentials respectively, the other quantities being constants of the apparatus.

BACK COUPLING IN L.F. AMPLIFIERS.—M. G. Scroggie. (*Wireless World*, 14th December, 1927, pp. 782-786.)

Discussion of the effects of anode supply impedance on the performance of amplifiers.

RESISTANCE AMPLIFIERS.—P. Tyers. (*Electrical Review*, 18th November, 1927, p. 885.)

A letter replying to Mr. Phillips' discussion, in the *Review* of 23rd September, of the writer's article in the *Review* of 9th September.

REACTION AND SELECTIVITY.—A. P. Castellain. (*Wireless World*, 7th November, 1927, pp. 757-758.)

An inquiry as to whether the effects of circuit resistance can be entirely annulled by reaction.

RECEPTION.

QUANTITATIVE DETERMINATION OF RADIO-RECEIVER PERFORMANCE.—(*Journ. Amer. Inst. E.E.*, 46, p. 1464, December, 1927.)

Discussion at Pittsfield meeting of Mr. Oakley's paper published in this Journal for May, 1927, p. 487.

RECTIFIERS AND SMOOTHING CIRCUITS.—F. Record and I. H. Holmes. (*Wireless World*, 28th December, 1927, pp. 841-843.)

An experimental study of input and output wave forms by means of the Duddell oscillograph.

A NOTE ON VOLUME CONTROL.—(*Wireless World*, 28th December, 1927, p. 852.)

THE LAST STAGE.—(*Wireless World*, 30th November, 1927, pp. 739-742.)

Some observations on the need for power in order to secure quality, and a consideration of the relative merits of super-power valves, valves in parallel, and valves in push-pull.

THE POWER SUPPLY OF WIRELESS SETS.—G. F. J. (*Electrical Review*, 18th November, 1927, pp. 856 857.)

The "battery-less" receiver: some experiences of an engineer who constructed a set incorporating three valves with indirectly heated filaments.

SUR UNE VÉRIFICATION DE LA THÉORIE DES DÉTECTEURS ET REDRESSEURS À CONTACT (On a verification of the theory of contact detectors and rectifiers).—M. Dubar. (*Comptes Rendus*, 185, pp. 1023-1024, 14th November, 1927.)

Pélabon's experiments have shown that an electric current can pass through an insulating layer of sufficiently small thickness separating two

conductors; but in general the whole thus constituted is endowed with different conductivity according to the direction of the current. When the opposite faces do not present significant differences of curvature, electronic theory indicates that the current will pass more easily from the conductor which is the poorer in free electrons to the richer conductor than in the reverse direction. The author describes experiments supporting this theory. An extremely thin insulating film of silica was deposited by electrolysis on the surface of a lump of silicon, and then graphite placed in contact with the film and pressure applied. The current-voltage curve of the complex conductor thus obtained was plotted. With the same voltage, the current in the direction silicon-graphite was very much greater than that in the reverse direction, and alternating current of relatively high frequency was rectified. The direction of greater conductivity is in accord with theory, silicon being much more resistant than graphite and consequently poorer in free electrons. It is curious to note that if an electrolytic rectifier is made, employing the same piece of silicon and a carbon pencil in dilute sulphuric acid, the direction of the current is reversed, that is from the carbon to the silicon. This is explained by the fact that the relative proportion of free electrons is changed round, the electrolyte not containing any (but only ions) while the silicon does contain free electrons, ts conductivity being of a metallic nature.

VALVES.

THE COSSOR SCREENED VALVE.—(*Wireless World*, 21st December, 1927, pp. 817-818.)

The valve's characteristic curves are shown and practical hints are given for best conditions of working.

DIRECTIONAL WIRELESS.

ON THE WIRELESS BEAM OF SHORT ELECTRIC WAVES (VIII).—S. Uda. (*Journ. Inst. Elect. Eng. Japan*, 471, pp. 1092-1100.)

A paper considering the horizontally polarised wave projector. The action of horizontal wave directors is studied in detail and compared with that of vertical wave directors (*J.I.E.E. Japan*, No. 467; these Abstracts, October, 1927, p. 639). In the present case, of course, each of the wave reflector and director rods is placed horizontally along the ground. It is pointed out that the length of the wave directors is the most important factor in improving directivity and consequently increasing the energy received. The results of field measurements are given and polar diagrams shown, proving that a sharp beam of horizontally polarised waves was produced.

In these experiments the wavelength employed was 441 cms., the length of each director being 200 cms. and the distance apart 150 cms. The field was measured by means of a horizontal receiving antenna which included a thermo-couple and a micro-ammeter.

ON THE WIRELESS BEAM OF SHORT ELECTRIC WAVES (IX).—S. Uda. (*Journ. Inst. Elect. Eng. Japan*, 472, pp. 1201-1219.)

The effects of wave reflector and director on the sending antenna circuit are studied theoretically with reference specially to the following points:

1. Effect on antenna current.
2. Effect on antenna power.
3. Wave reflector and director characteristics at constant antenna current and power.
4. Directive polar diagrams at constant antenna current and power.

Some results obtained experimentally are also shown and compared with those calculated.

MEASUREMENTS AND STANDARDS.

ON THE BRIDGE TYPE OF VALVE VOLTMETER.—I. Yamamoto and K. Morita. (*Journ. Inst. Elect. Eng. Japan*, 471, pp. 1051-1064.)

Description of a new instrument for measuring very small alternating voltages, consisting of a balanced high resistance bridge, two symmetrically placed triode rectifiers, and a d'Arsonval galvanometer.

If a small voltage is applied to one diagonal of the bridge, and an auxiliary voltage of the same frequency to the other diagonal, the galvanometer gives a deflection proportional to the scalar product of these two voltages. The voltage sensitivity of the arrangement can be varied by choosing the auxiliary voltage over a wide range, the maximum sensitivity obtained in this experiment being 2.4 mm. for one millivolt with an auxiliary voltage of 8 volts.

The apparatus can also be conveniently used for the very precise comparison of radio frequencies, a difference of one-tenth of a cycle being detectable by the authors' method.

THE POWER-FACTOR AND CAPACITY OF THE ELECTRODES AND BASE OF TRIODE VALVES WITH SPECIAL REFERENCE TO THEIR USE IN THERMIONIC VOLTMETERS.—G. W. Sutton. (*Proc. Phys. Soc.*, 40, pp. 14-22, December, 1927.)

The paper discusses the conditions under which a three-electrode valve-voltmeter should be operated to ensure a minimum power consumption, and at the same time to give indications closely proportional to the square of the input voltage. A simple method of adjusting the operating voltages to fulfil the necessary conditions is described.

This paper is briefly referred to in *E.W. & W.E.* for January, 1928, p. 16.

IMPIEGO DELL'OSCILLOGRAFO NELLO STUDIO DELLE CORRENTI RADIOTELEGRAFICHE (The employment of the oscillograph in the study of the currents of radiotelegraphy).—G. Pesson and T. Gorio. (*L'Elettrotecnica*, 25th November, 1927, pp. 849-856.)

Description of the apparatus and method, showing several typical oscillograms.

A MECHANICAL HARMONIC ANALYSER FOR CATHODE RAY OSCILLOGRAMS. — C. F. Wiebusch. (*Journ. Opt. Soc. Amer.* and *Rev. Sci. Instr.*, 15, pp. 355-358, December, 1927.)

Description of an instrument which will analyse oscillograms obtained from the cathode ray oscillograph when the reference field is sinusoidal, and is adjustable to take care of oscillograms of various sizes. The analyser can also be used for curves

plotted on a uniform base. The particular instrument described was made to analyse up to and including the tenth harmonic.

ABBREVIATED METHOD FOR CALCULATING THE INDUCTANCE OF IRREGULAR PLANE POLYGONS OF ROUND WIRE.—V. J. Bashenoff. (*Proc. Inst. Radio Engineers*, 15, pp. 1013-1039, December, 1927.)

A paper containing the first part of an investigation on the design and use of closed aerials (calculation of the inductance for single-turn aerials). Two methods are given for determining the inductance for closed aerials and, in general, plane figures of any shape, having no re-entrant angles. The first method is based on the author's supposition of the practical equivalence of the inductance of any figure and the inductance of a right triangle or rectangle, having area and perimeter equal to those of the given figure. The second method is a development of the basic assumption of the first, and results in the derivation of a simple formula for all possible figures, including curved ones.

Numerous tests of the correctness of both methods by practical measurements on closed aerials with a height of the point of support from 65 down to 2 metres have fully confirmed the author's conclusions.

PIEZO-ELECTRIC RESONANCE AND OSCILLATORY PHENOMENA WITH FLEXURAL VIBRATIONS IN QUARTZ PLATES.—J. R. Harrison. (*Proc. Inst. Radio Engineers*, 15, pp. 1040-1054, December, 1927.)

A method is given of obtaining flexural vibrations from piezo-electric quartz plates together with the equations for flexural vibrations in quartz. Crystal mountings for obtaining best results with the first, second, and higher modes of flexural vibration are developed. Description is also given of the use of the crystal at flexural frequencies in the oscillator circuits of Cady and Pierce, and the luminous phenomena obtained when resonating in a partially evacuated chamber with different types of mountings. Without employing unusually long plates the range of frequencies obtainable is extended into the audible range.

Among the problems still to be solved are the temperature coefficient of frequency and logarithmic decrement for the various modes of flexural vibration as well as constancy of frequency under variations of load and constants of the electric circuit. Investigation is still in progress, a report of which will be communicated later.

SUBSIDIARY APPARATUS.

STORY OF THE HORNLESS LOUD-SPEAKER.—(*Wireless World*, 21st December, 1927, pp. 806-810.)

An historical survey of the development of free-edge, fixed-edge and inertia-controlled cone loud-speakers from 1879 to the present day.

STATIONS: DESIGN AND OPERATION.

5SW, CHELMSFORD.—(*Wireless World*, 30th November, 1927, pp. 737-738.)

Illustrated account of the new 20 kW experimental transmitter at Chelmsford for empire broadcasting, working at present on a wavelength of 24 metres.

GENERAL PHYSICAL ARTICLES.

SUR LE RÔLE DE L'OZONE DANS L'ATMOSPHERE (On the part ozone plays in the atmosphere).—J. Lévine. (*Comptes Rendus*, 185, pp. 962-963, 7th November, 1927.)

The most distinct result of the first year of a system of simultaneous observations of the ozone at different places is that the richness of the atmosphere in ozone is closely linked with the distribution of atmospheric pressure, ozone being more abundant in depressions than in anticyclones.

THE PHOTOELECTRIC CONDUCTIVITY OF SULPHUR.—B. Kurrelmeyer. (*Phys. Rev.*, December, 1927, pp. 873-910.)

Experiments are described, the results of which suggest that sulphur has a polar axis due to atomic asymmetries and should show the piezo- and pyro-electric effects.

A THEORY OF IMPERFECT SOLID DIELECTRICS.—M. G. Malti. (*Journ. Amer. Inst. E.E.*, 46, pp. 1373-1380, December, 1927.)

Abridgment of a thesis summarising the experimental facts regarding the anomalous behaviour of solid insulating materials under varying conditions of potential, time, temperature, frequency, humidity, ionising radiations and various other factors; and establishing hypotheses accounting in a general way for the behaviour observed.

STUDY OF THE HIGHER NATURAL OSCILLATIONS OF SOLENOIDAL COILS.—I. Yamamoto. (*Journ. Inst. Elect. Eng. Japan*, 471, pp. 1101-1129.)

Report of an experimental investigation of the higher natural electrical oscillations of solenoidal coils of finite length.

The coil specimens under experiment, all wound on octagonal frames made of ebonite bars with cotton-covered copper wires, included fourteen different coils of the single layer type.

The higher natural wavelengths were measured when both ends of the coil were free and also when one end was earthed, and it was concluded from the experimental results that the ratio of the fundamental natural wavelength λ_1 to the higher natural wavelength of the mth order λ_m could be practically represented by a linear equation

$$\lambda_1/\lambda_m = 1 + \alpha(m - 1),$$

where the coefficient α is a function of the dimension ratio $h/2r$ of the coil.

A qualitative explanation of these results is given, taking into account the mean propagation velocity of electrical disturbance along the length of the coil.

NEW METHODS OF ELECTRICALLY MAINTAINING MECHANICAL OSCILLATIONS.—J. H. Vincent. (*Nature*, 31st December, 1927, p. 952.)

An outline of methods which may find application such as the providing of sources of oscillations and frequency standards.

CONSEQUENCES OF A MATRIX MECHANICS AND A RADIATING HARMONIC OSCILLATOR WITHOUT THE QUANTUM POSTULATE.—A. Press. (*Phil. Mag.*, 4, pp. 1249-1261, December, 1927.)

PHÉNOMÈNES OPTIQUES PRÉSENTÉS PAR LE QUARTZ MIS EN VIBRATION PIÉZO-ÉLECTRIQUE (Optical phenomena presented by quartz set in piezo-electric vibration).—R. Moens and J. E. Verschaffelt. (*Comptes Rendus*, 185, pp. 1034-1036, 14th November, 1927.)

DEMONSTRATION OF HIGH-FREQUENCY FLUCTUATIONS IN THE INTENSITY OF A BEAM OF LIGHT.—C. O. Browne. (*Proc. Phys. Soc.*, 40, p. 36, December, 1927.)

Brief description of an experiment, due to Prof. Kerr Grant, in which a beam of light is made to fluctuate in intensity at radio frequencies in synchronism with the piezo-electric oscillations of a quartz crystal.

FREE MOTION IN THE WAVE MECHANICS.—C. G. Darwin. (*Proc. Roy. Soc.*, A.117, pp. 258-293, December, 1927.)

Whereas hitherto the wave mechanics has mostly been applied to a study of stationary states, the present paper deals with its application to cases where there is a *progress* of events. After a review of principles and a description of the new way in which motion must be regarded, the following problems are discussed :—

The free motion of an electron under no forces.

The motions of an electron in uniform electric and magnetic fields.

The motion of an electron in an atom.

The motion of an atom in a uniform magnetic field.

The Stern-Gerlach effect.

The motion of the spinning electron.

THERMODYNAMICS, WAVE-THEORY, AND THE COMPTON EFFECT.—C. V. Raman. (*Nature*, 31st December, 1927, p. 950.)

MISCELLANEOUS.

COLOUR BY WIRE OR RADIO.—(*Journ. Amer. Inst. E.E.*, 46, p. 1380, December, 1927.)

A new invention for matching colours is reported at the Massachusetts Institute of Technology. The colour specimen is placed in a holder close to a high-power electric lamp. Light is alternately reflected from it and from a block of magnesium carbonate, the whitest of the world's substances, and variation of reflection from these two surfaces is registered by a photo-electric cell and transmitted in electrical impulses by either wire or radio. Exact reproduction of any shade can be made without the possibility of visual error, thus advancing the industries from dependence upon the human eye.

QUANTITATIVES ÜBER STRASSENBAHNSTÖRUNGEN DES RUNDFUNKEMPFANGES (Quantitative results on the disturbance of broadcast reception by trams).—W. Bernitt. (*Zeitschr. f. techn. Physik*, 8, pp. 410-421.)

Description of experiments in which the intensity of the noise disturbing radio reception, that occurs when the trolley of a street electric tram is taken off, is compared with the intensity of a standard source of disturbance, by means of a travelling receiver. Investigation is made of the disturbances along and perpendicular to the line, of the influence of the material of which the trolley is made and the insertion of condensers.

THE MOVIETONE.—W. I. G. Page. (*Wireless World*, 14th December, 1927, pp. 789-792.)

BRITISH TIME SIGNALS FROM RUGBY, GBR.—(*Wireless World*, 28th December, 1927, p. 843.)

Account of this new service to navigators, astronomers and geographical expeditions.

Esperanto Section.

Abstracts of the Technical Articles in Our Last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en Nia Lasta Numero.

PROPAGADO DE ONDOJ.

LA MALDENSECO DE SENFADENAJ ONDOJ SUPER LA TERO.—Resumo de prelego legita de S-ro. R. H. Barfield, M.Sc., A.M.I.E.E., ĉe la Senfadena Sekcio, Institucio de Elektraj Inĝenieroj, Londono, je 7a Decembro, 1927a.

La prelego priskribas mezuradojn de intenseco faritajn per portebla aparato je normalaj sendadoj el la Londona Brodkasta Stacio, laŭlonge de sep malsamaj direktoj, kaj je distancoj de 5 ĝis 100 mejloj.

La aparato kaj mezura sistemo estas priskribitaj kaj la rezultkurvoj montritaj. Oni utiligis ĉi tiujn por konstrui konturan mapon de kampaj fortecoj, kaj ili estas poste reduktitaj al norma formo kaj komparitaj kun teoriaj rezultoj kalkulitaj laŭ la laborado de Sommerfield pri la teorio de maldenseco. Oni montras, ke la maldenseco estas pli granda laŭ unuj direktoj, ol laŭ aliaj, estante rimarkinde pligranda laŭ direkto Suden el Londono, ol laŭ direkto Norden, dum laŭ ĉiuj direktoj la maldenseco estas pligranda ol la teorio antaŭdiras.

La aŭtoro tiam sugestas, ke ĉi tiu pligrandigita maldenseco estas kaŭzita de l'efekto de arboj, la angla kamparo estante plejparte dense arbita. Oni priskribas eksperimentojn pri mezurado de la efekto de arbo, kaj esprimo estas derivita montranta la nombron da arboj por unuo-areo bezonita por sorbi tiom da potenco, kio egalas tion sorbitan de

la tero. Efektivaj nombradoj de l'arboj en la diversaj distriktoj montras, ke la Suda regiono estas plidense arbita, kaj oni konkludas, ke la efekto de arboj multe helpos klarigi la diversajn efektojn, kaj la forirojn for de la teoriaj valoroj.

Raporto pri la diskutado, kiu sekvis la legadon de la prelego, estas ankaŭ donita.

PROPRECOJ DE CIRKIVITOJ.

La Stabileco de la Altfrekvenca Amplifikatoro kun Agordita Krado kaj Agordita Plato.—R. T. Beatty.

En la enkonduko la aŭtoro atentigas la mankon de kvanta traktado pri la valoro de reakcio, kaj ke, per ŝirmitaj valvoj, altfrekvencaj amplifikatoroj povas nun esti konstruitaj kun perfekta stabileco kaj kun la reakcio regita kaj kalkulebla. Oni povas ĉiam faciligi la kalkuladon, anstataŭigante rezistancojn per la interrespondaj konduktancoj.

De la ekvivalento de tipa paralela cirkvito, li nun alpaŝas al la okazo de la cirkvito kun agordita krado kaj agordita plato, kaj tiam disvolvigas ekvaciojn de l'amplifikatoro. Oni montras, ke A estas la amplifeco, kiu ekzistus se retro-kuplo estus for, kaj la cirkvitoj agorditaj laŭ la signalo, dum H estas valoro dependanta de cirkvitaj konstantoj. F kaj H povas esti prezentitaj sur parabolo, per kio la gajno de reakcio estas legebla per ekzameno. Li tiam disvolvigas la geometrian signifon de H & F, montrante la konstruon de la parabolo aludita. Numera ekzemplo estas donita, kaj la alproksimiĝo al malstabileco diskutita, dum la tuta ŝtupa gajno kaŭze de A kaj F estas taksita.

La rezonado (ĝis nun limigita al valvo, traktita kiel norma en la prelego) estas tiam etendita por apliki al iu ajn valvo. La maksimuma ŝtupa gajno G (kun fiksaj kondensatoroj kaj varieblaj bobenoj) estas poste diskutita kaj por la norma kaj por iu ajn valvo, dum fine la rezonado estas aplikita al la plikutima praktika ekzemplo kovri vastan skalon de agordado per bobenaro kun variebla kondensatoro. Ĉi tiu ekzemplo estas ilustrita per "ŝtupetara" serio de kurvoj, ĉiu "ŝtupo" interrespondanta al la agorda skalo de aparta paro da similaj bobenoj uzitaj en la kradaj kaj anodaj cirkvitoj respektive.

HELPA APARATO.

La Kupro-oksida Rektifikatoro.

Redakcia artikolo traktas pri ĉi tiu tipo de seka rektifikatoro. Se oni formas tavolon de oksido sur folio de kupro kaj faras kontakton per peco de plumbo premita kontraŭ la oksido, la rezisteco kontraŭ kurento pasanta de plumbo al kupro estas malpli ol tio en la kontraŭa direkto. Por aplikita tensio de 5 aŭ 5 voltoj la proporcioj de ĉi tiuj rezistecoj estas ĉirkaŭ 12,000.

Karakteriza kurvo de la rektifikatoro estas donita, kaj la konstruo de l'rektifikatoro ilustrita, dum diagramoj estas ankaŭ donitaj pri la utiligo de grupoj da ĉi tiuj rektifikatoroj por bateria ŝargado, kun fotografaĵoj de komercaj produktaĵoj.

La Korekteco kaj Normigada Daŭreco de Varieblaj Aer-kondensatoroj por Precizecaj Ondometroj.—W. H. F. Griffiths.

La aŭtoro **unue** atentigas, ke la korekteco de subnorma ondometro estas ĉiam limigita de la konstanteco de ĝia variebla aera kondensatoro kaj de ĝia grado de leĝo-konformeco.

En Parto I de l'artikolo, la aŭtoro diskutas ĉi tiujn dubecojn pri kapacito. Montrinte unue la pligrandan alproksimiĝon al konstanteco de dekremento obtenita per utiligo de variebla kondensatoro kaj fiksaj bobenoj (kontraŭ fiksa kondensatoro kaj varieblaj induktancoj), li nun diskutas la malfacilaĵojn de variebla kondensatora konstruado. Estas necese, ne nur, ke la platoj estu perfekte paralelaj, sed ankaŭ, ke ĉiu mova plato rotaciu ĝuste meze inter sia paro da fiksaj platoj (vidu S-rojn. Braillard kaj Divoire, en *E.W. & W.E.*, Junio, 1927a). La ĝenerala efekto de interspac-egaligo estas poste diskutita detale, kaj rilate al daŭreco kaj rilate al leĝo-konformeco, la diskutado estante bone ilustrita per grafikaĵoj. Ekzemplo de moderna precizeca kondensatora korekteco estas ankaŭ citita kaj ilustrita.

En Parto II la aŭtoro priskribas novan desegnon de variebla kondensatoro. La necesega trajto estas, ke apudaj dielektrikaj interspacoj estas en seria formo, anstataŭ paralela, kaj estas ankaŭ komplementaj. Laŭ sia plej simpla formo tia kondensatoro konsistas el tri platoj, du fiksaj kaj unu mova. La du fiksaj platoj estas izolitaj unu for de l'alia, kaj agas kiel la bornoj de l'instrumento. La mova plato estas interfoliita inter ili kaj estas izolita for de ambaŭ, kaj oni montras, ke la kapacito estas inverse proporcia je la sumo de la du grupoj, kiu restas konstanta, ĉu la mova plato estas centrigita aŭ ne. La aranĝo estas montrita, aplikite al pligranda nombro da platoj, utiligante similan principon.

La artikolo estas daŭrigota.

La Potenca Faktoro kaj Kapacito de l'elektrodoj kaj fundo de Triodoj.

Jen raporto pri prelego legita kun ĉi-supra titolo de S-ro. G. W. Sutton ĉe la Fizika Societo de Londono. Oni diras ke, aparte ĉe valva voltmetra aranĝo, la valvtenilo kaj fundo eble enkondukos konsiderindajn perdojn. Antaŭa sugesto (de Hartshorn kaj Jones), ke la vitra parto estas plikulpa ol la miksaĵa fundo, ne estas subtenita de S-ro. Sutton. Ĉi tiu aŭtoro donas ciferojn pere de Tabelo montranta kapaciton lau $\mu\mu$F kaj Potencan Faktoron por kelkaj malsimilaj valvoj kun aŭ sen iliaj fundoj.

DIVERSAĴOJ.

Resumoj kaj Aludoj.

Kompilita de la Radio-Esplorada Komitato (*Radio Research Board*), kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

Indekso.

La nuna numero enhavas Indekson por Volumo IV, kompletigita per la numero de Decembro 1927a.

La Indekso estas dividita laŭ tri partoj:—

I Ĝenerala Indekso (Titoloj),
II Nomoj de Kontribuintoj,
III Resumoj kaj Aludoj.

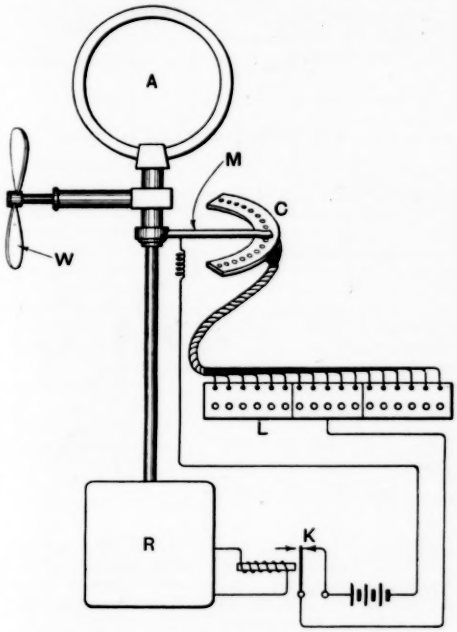
Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

AIRCRAFT D.F. INSTALLATION.

(*Convention date* (*Germany*), *20th March*, 1926. *No.* 267969.)

In order to simplify the process of taking bearings by wireless, whilst in the air, a D.F. installation is designed to give the pilot the required information



automatically by means of a flash-lamp indicator. The loop aerial A is driven either by a windscrew W, or from the main propeller, so that it swings constantly to and fro over an angle of say 90 degrees. Somewhere within this sector it will bear directly on the transmitter station, in which position no signal energy is received. At this critical point a flash-lamp illuminates as follows :—

Attached to the rotating shaft of the frame aerial is an arm M which sweeps over a series of contacts C. These are connected through a corresponding bank of indicator lamps L in a local circuit containing an electromagnetically-controlled contact K. So long as there is any pick-up energy in the aerial A, the output from an amplifier R is sufficient to maintain the contact points K open. At the precise point of zero reception, however, the amplifier output falls, the contact K closes, and the local circuit operates to illuminate the particular lamp L which corresponds to the position of the arm M, thus giving the pilot a visual indication of the required bearing. Instead of using the lamps L, a single Neon tube may be mounted to rotate over a compass dial, in synchronism with the loop aerial, the point of minimum reception being indicated by the sudden extinction of the Neon glow as the voltage from the amplifier drops

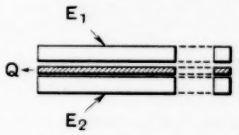
Patent issued to the Telefunken Co.

LUMINOUS FREQUENCY-INDICATORS.

(*Convention date* (*Germany*), *15th May*, 1925. *No.* 252170.)

A rod Q of rock crystal, some centimetres in length and a few square millimetres in cross-section, rests freely on a lower metal electrode E_2. A narrow space filled with rarefied air or other gas separates it from an upper metal electrode E_1. Under these conditions when the crystal is excited by electric oscillations corresponding to its fundamental frequency, the resulting piezo-electric voltage acts to ionise the rarefied air and so produces a luminous glow.

If the exciting frequency is the nth harmonic of the fundamental crystal frequency, n evenly-spaced bands or zones of light appear in the vacuous space. In this way the effect may be utilised to give a visual indication of the presence of any particular frequency, within the limits of the crystal dimensions. By mounting together several crystal rods, cut to different sizes, the arrangement can be used to give a visual indication, for example,



of fluctuations in the carrier wave-length of a transmitting station, any variation from the allotted frequency being accompanied by a shifting of the luminous bands.

Patent issued to E. Giebe and A. Scheibe.

TELEVISION SYSTEMS.

(*Convention date* (*Germany*), *19th January*, 1926. *No.* 264816.)

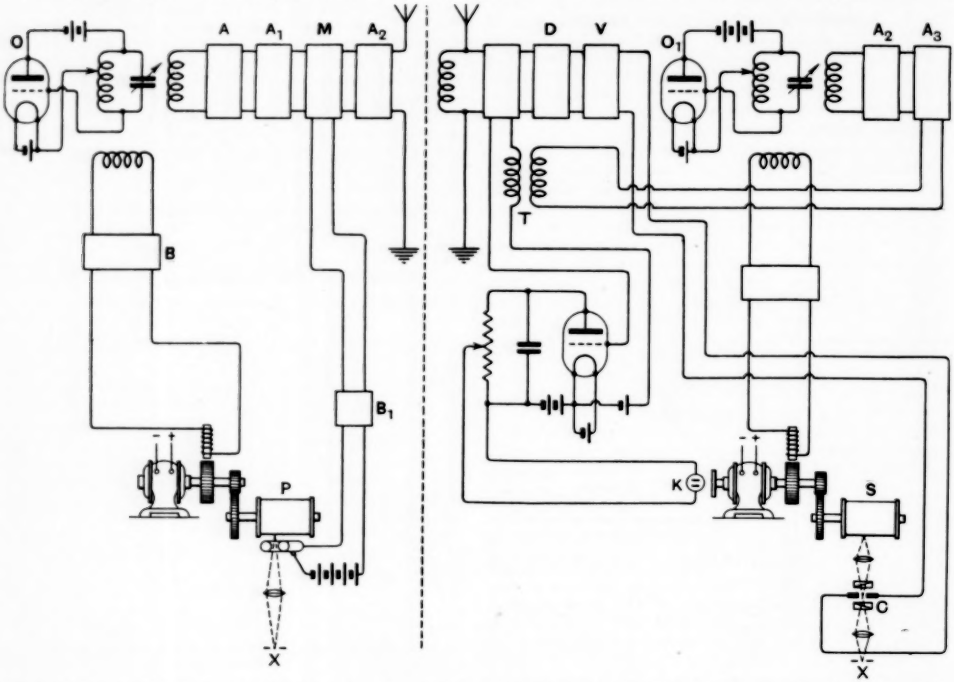
In a system of television or picture-transmission, the picture-analysing device at the transmitting end is synchronised with the picture-building apparatus at the receiving end through the medium

of the carrier-frequency on which the actual signalling elements are superimposed. For transmission a constant-frequency tube O generates a basic frequency of, say, 1,500 cycles per second. This is raised by harmonic selectors, A, A_1 to, say, 150,000 cycles.

Simultaneously the 1,500 cycle frequency is fed through an amplifier B to control a synchronous motor or La Cour wheel which drives the picture-transmitting drum P. The picture-signalling elements are first passed through an amplifier B_1 and are then used to modulate the 150,000 cycle frequency at M, the resulting complex wave being fed to the transmitting aerial.

At the receiving station, shown on the right-hand side of the figure, a constant-frequency oscillator O_1 generates a similar basic frequency of 1,500 cycles, which instead of being multiplied a hundred-fold as in transmission, is increased ninety-nine-fold by harmonic selectors A_2, A_3. This higher frequency is transferred at T and heterodynes with the incoming carrier wave. The resulting beat-note of 1,500 cycles is applied through an amplifier and a Kerr cell to exercise a stroboscopic control of the synchronous motor driving the picture-building drum S. Meanwhile the incoming signal components are detected at D and, after amplification at V, are applied to a light-control cell which is interposed between a source of light X and the drum S.

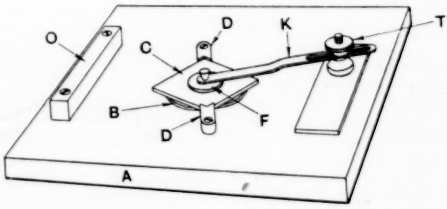
Patent issued to A. Karolus.



QUARTZ OSCILLATORS.

(*Application date 14th September, 1926. No. 279595.*)

It is found that the output which can be controlled by a quartz crystal varies very considerably with the method of mounting the crystal. In particular, it depends (*a*) upon the asymmetrical position of the electrodes with respect to one another and of the crystal with respect to the electrodes (*b*) upon the shape and size of the electrodes relatively to the crystal, and to one another, and (*c*) upon the pressure of the electrodes against the crystal, or upon the air-gap left between the crystal and electrodes.



An adjustable mounting in which all the relevant

factors can be controlled comprises a baseboard *a* of soft wood covered with velvet. The crystal *C* is mounted between a lower metal plate or electrode *B*, which is of approximately the same area as the crystal, and an upper electrode *F* which is considerably smaller. The latter is connected to a screw terminal *T* by a cranked strip *K* of metal capable of exerting a variable pressure.

When mounting the crystal, it is first suitably placed with respect to the bottom electrode *B*, and is then fixed in position by the side members. The upper electrode *F* is next adjusted as desired over the top surface of the crystal, and is then clamped by turning the screw terminal *T*. A ledge *O* is provided on the baseboard as shown, at approximately the same level as the top of the electrode *F*, so that an extra weight can be applied, if desired, by laying it across the ledge on to the upper electrode.

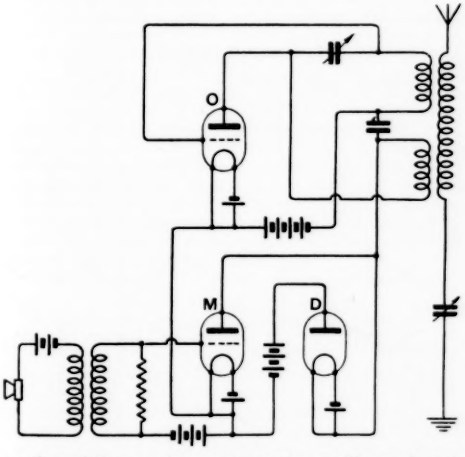
Patent issued to A. Hinderlich.

CHOKE MODULATORS.

(*Application date 1st July*, 1926. *No.* 279535.)

In the ordinary arrangement of choke control, it is found that the total space-current consumed by the oscillator and modular tubes is not maintained constant over the whole range of frequencies. At the lower frequencies, unduly large currents flow through the choke and thus tend to reduce the efficiency of transmission.

In order to overcome this defect a saturated *diode* or Fleming valve *D* is inserted in the common



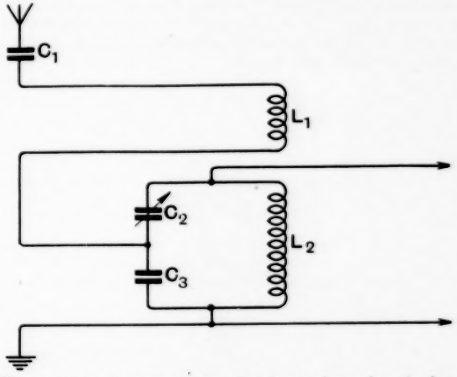
portion of the anode supply to the oscillator *O* and modulator *M*. Since the tube *D* will only permit the passage of a steady, or substantially invariable current, which represents the total anode consumption of the oscillator *O* and modulator *M*, any variation in the current passing through the latter must be accompanied by a corresponding change in the current flowing through the oscillator, thus ensuring a constant percentage modulation of the outgoing carrier wave.

Patent issued to D. O'B. T. McAteer and W. A. Beatty.

A CONSTANT-COUPLING CIRCUIT.

(*Convention date (U.S.A.), 8th August*, 1925. *No.* 256644.)

The aerial circuit C_1, L_1, C_3 is coupled to the secondary circuit C_2, C_3, L_2 partly through a fixed condenser C_3 and partly across the coils L_1, L_2.



The system is tuned to the incoming signals by means of the variable condenser C_2. As the signal frequency rises, the reactance of the fixed condenser C_3 increases, and the energy-transfer across it falls off accordingly. Simultaneously the coupling across the coils L_1, L_2 increases, so that the two effects tend to counterbalance each other.

The total capacity reactance of the secondary circuit consists of the two condensers C_2, C_3, and the effective capacity coupling will therefore depend upon the relative value of these two components at any given moment. By suitably adjusting this value, the increase in inductive coupling can be made to compensate exactly for the decrease in capacity coupling, whereby the overall energy-transfer is maintained constant throughout a wide range of tuning.

Patent issued to S. Y. White.

LIGHT-SENSITIVE CELLS.

(*Application dates, 30th August*, 1926 *and 12th March*, 1927. *No.* 279937.)

In order more effectively to control the electron emission inside a photo-electric cell, a third or control electrode has been inserted between the anode and cathode to function in the same manner as the grid in an ordinary three-electrode valve. It is found, however, that the presence of this grid or control introduces undesirable capacity coupling. The present invention therefore consists in the provision of a fourth electrode or screening grid, located between the grid and the anode, which does not impede the normal electron flow inside the

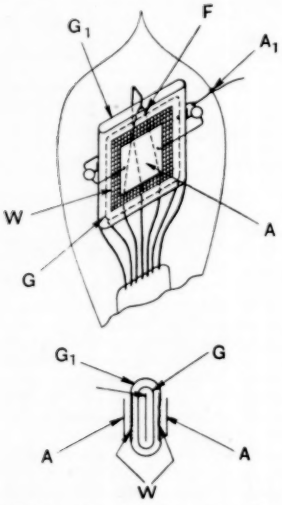
cell, but which operates to prevent inter-electrode capacity coupling.

Patent issued to N. S. Smith and N. W. McLachlan.

SCREENED-GRID VALVES.

(*Application date, 22nd July, 1926. No. 279171.*)

As originally constructed the screened-grid valve necessitated a special type of holder, owing to the fact that the connections to the electrodes were made at both ends of the tube. According to the present invention the construction is modified in order to allow the valve to be mounted on a standard four-pin base. The arrangement of the electrodes is shown in elevation in the upper figure and in plan in the lower figure.



The anode lead A_1 is fused into the side of the glass tube, whilst the remaining connections are made through a four-pin base in the ordinary way. A hairpin filament F is surrounded by an open spiral control grid G which, in turn, is enclosed inside the outer or screening grid G_1. This is made of a flattened cylinder provided at each side with mesh-work windows W. The anode consists of a pair of plates A connected to the common lead A_1 and mounted close to each window.

Patent issued to H. J. Round.

RECTIFIERS.

(*Application date, 12th November, 1926. No. 279259.*)

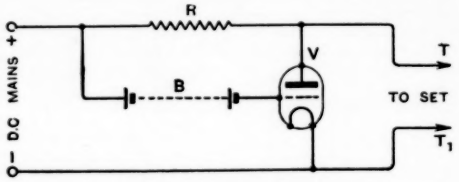
Silicon, either in solid form, or in combination with an aqueous electrolyte, such as an alkaline hydroxide, carbonate, etc., or sulphuric, nitric, or hydrochloric acid, is used as a rectifier for alternating current of the order supplied for domestic lighting. Its action in this respect is distinguished from its known use as a detector of radio-frequency currents. The rectifying electrode is preferably formed of solid silicon of comparatively large size, or a metal plate with a surface coating of silicon may be used. For dry-contact rectification a number of silicon plates in contact with silicon oxides or sulphides are employed.

Patent issued to L. P. Bensing.

D.C. SMOOTHING DEVICES.

(*Application date, 10th September, 1926. No. 279214.*)

In order to steady the voltage supplied by D.C. mains to the high-tension circuits of a valve receiver, an impedance R is inserted in series with one of the mains, and the anode-cathode circuits of one



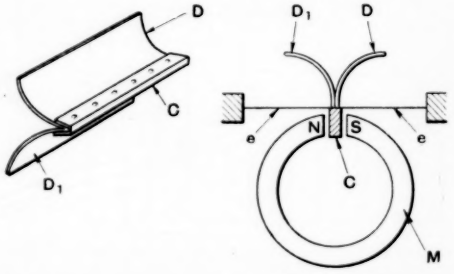
or more valves V are bridged across the mains between the impedance and the load. The grid of the valve V is connected through a battery B to the positive main as shown. Should the potential of the main supply rise, the resulting back E.M.F. across the impedance R throws the grid more positive, so that more current flows through the valve, and *vice versa*, thus maintaining a constant voltage across the terminals T, T_1. The correct value of the impedance R is determined by the mutual conductance of the valve V.

Patent issued to W. J. Brown and the Metropolitan Vickers Co.

LOUD-SPEAKERS

(*Convention date (Germany), 15th March, 1926. No. 267564.*)

In the folded or arched diaphragms of the type shown, the junction of the edges D, D_1 is enclosed by a metal rib C which is inserted in the narrowest possible gap between the poles of the magnet M.



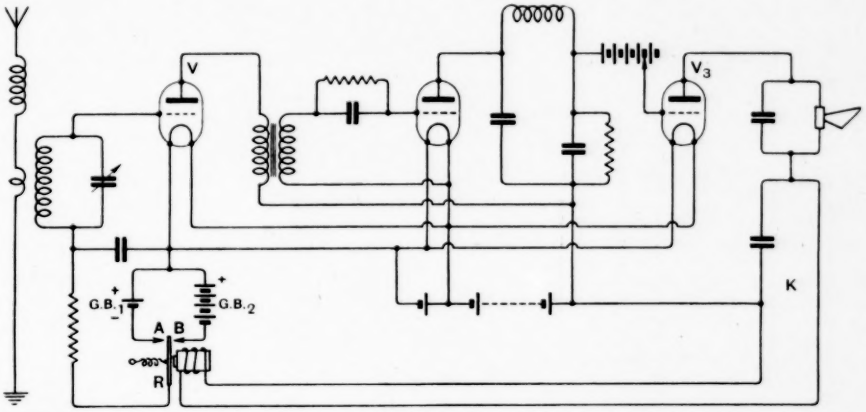
The electrodynamic forces tending to vibrate the diaphragm are thereby distributed along the conducting rib in a uniform fashion, so that rattling or chattering is avoided. The rib C may be supported laterally by elastic bands or threads.

Patent issued to the Siemens and Halske Co.

SIGNAL-STRENGTH CONTROL.

(*Convention date* (*France*) 13*th April*, 1926. *No.* 269554.)

Relates to an automatic method of gain-regulation with the object of compensating for fluctuations in signal strength due to various causes such as fading. The sensitivity of the first valve V is controlled by the provision of two alternative grid-biasing batteries G.B.$_1$ and G.B.$_2$, the application of one or the other of these being made dependent upon the strength of current flowing in the output of the last valve V_3.



For maximum sensitiveness the arm of the relay R will rest against the contact A so as to impose a small negative potential from G.B.$_1$ on the grid of valve V. Should the output from the amplifier V_3 grow too strong, or tend to blast, the current in a branch circuit K operates an electro-magnet to swing the arm R over into contact with B, thus placing a strong negative bias from the battery G.B.$_2$ on the grid of the input valve.

A hot-wire ammeter may be used to operate the arm R in place of the electro-magnet shown. This arrangement is particularly useful in regulating the output from a receiver intended for alternate distant and close-range reception.

Patent issued to H. J. M. R. de Bellescize.

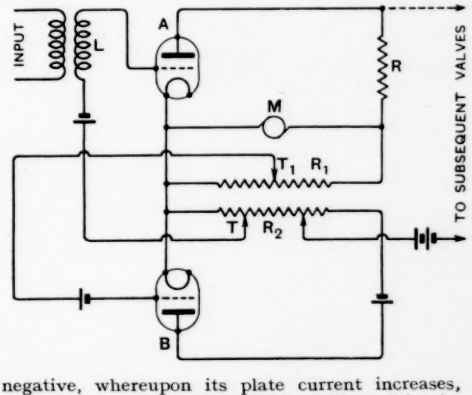
MAINS-SUPPLY UNITS.

(*Application date*, 19*th August*, 1926. *No.* 280645.)

In order to minimise the effect of fluctuations in the plate or filament supply to a valve set fed directly from the mains, an auxiliary valve is so arranged as to apply to the first valve a compensating grid voltage proportional to, and in phase with, the disturbance. As shown in the Figure, the plate voltage for the first valve A is taken from a dynamo M. The plate circuit is completed through two resistances, R, R_1.

The plate circuit of the auxiliary or compensating valve B is completed through a battery and series resistance R_2. A tapping T is taken from the resistance R_2, through a bias battery and the input coil L to the grid of the main valve A, whilst a similar tapping T_1 from the resistance R_1 goes to the grid of the valve B.

Should the voltage across the dynamo fall momentarily, then the voltage across the resistance R_1 falls also, and the grid voltage of the valve B becomes more negative, so that the plate current of that valve decreases. The voltage fall across the resistance R_2 is accordingly reduced, and the grid of the main valve A must therefore become less negative, whereupon its plate current increases, thus compensating for the initial falling-off in the power supply voltage.



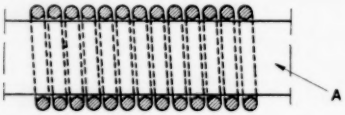
Patent issued to W. S. Smith and N. W. McLachlan.

A.C. VALVE FILAMENTS.

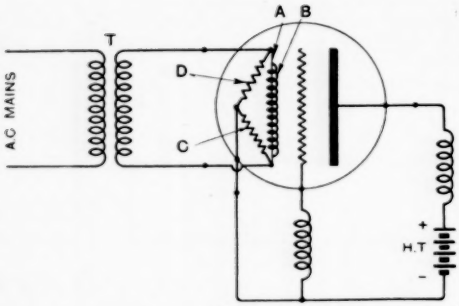
(*Convention date* (*France*), 2*nd March*, 1926. *No.* 267078.)

In order to allow the use of A.C. current from the mains for energising valve filaments, with a

minimum of "noise," the filament comprises a thick core *A* capable of taking a large heating-current, over which is wound a fine wire cathode *B* of thoriated tungsten or other material of high



(a)



(b)

emitivity. The resistance of the wire *B* is so great relatively to that of the core *A* that practically no "mains" current passes through it.

To prevent electrostatic induction, two equal resistance elements *C*, *D* are mounted inside the bulb, in parallel with the spiral cathode, and the junction point is connected directly to earth. Or the mid-point of the cathode proper may be earthed; or a potentiometer tapping may be made to a resistance shunted across the secondary of the filament transformer *T*.

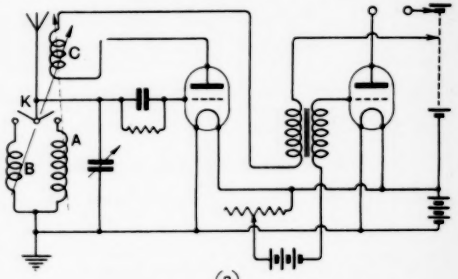
Patent issued to Société Luxor.

A FLEXIBLE TUNER.

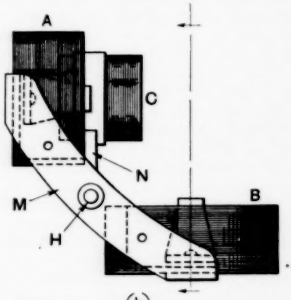
(*Convention date* (*U.S.A.*) *2nd December*, 1926. *No.* 279689.)

The circuit arrangement of a receiver designed to receive either short or long wave transmissions is shown in Fig. (a). Two aerial coils *A*, *B* are provided, together with a change-over switch *K*. In the left-hand position of the switch a short-wave coil *B* is brought into the aerial circuit, whilst in the right-hand position a coil *A* suitable for the long-wave Daventry transmission becomes effective. A common reaction coil *C* is made to serve for both settings.

The manner in which this is effected is shown in Fig. (b). Both the coils *A* and *B* are rigidly fixed to a common bracket *M*, being set at right angles to each other so as to minimise coupling. The common reaction coil is mounted on a link *N* pivoted at *H*, so that it can be swung from the



(a)



(b)

position shown into close coupling with the lower coil *B*, when the wavelength switch *K* is changed over to a new setting.

Patent issued to Brandes Laboratories Inc.

ERRATA.

"A Radio Signal-Intensity Recorder."—The record of reception on page 743 is reproduced half full size, and not full size as stated.

Abstracts and References.—On page 765 of the December number, column 2, immediately below Fig. 2, the "horizontal antennæ described above" should read "described below," as the reference is to the Abstract appearing under the same heading of "Directional Wireless" on page 766.

"The Stability of the Tuned-grid, Tuned-plate H.F. Amplifier."

Page 4.—Figs. 3 and 4 together constitute the component parts of Fig. 2.

Page 4.—Line 14: for "amplifiers" read "amplifier."

Page 8.—For section "9" read "9a."

Page 8.—Section 11: the references to "section 11" should be to "section 10."

Page 12.—Table II, for "166 $\mu\mu$F" read "160 $\mu\mu$F."